Appendix A: Concept Plans

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1. Palmetto Pines Golf Course

Project Location and Description

The project is located at Palmetto Pines Golf Course which is an unregulated facility, meaning the golf course isn't currently required by Southwest Florida Water Management District (SFWMD) to treat its runoff. Therefore, the concept for the golf course is to provide three options for consideration. Each can be constructed individually or combined in different configurations. The first and least expensive option is to increase the storage capacity of the existing pond system. Option two includes revising operations by pulling water via pump from the canal on the west side of the golf course. Option three includes the construction of 1 to 3 bioswales to treat runoff and improve flooding in the golf course. Figure A.1-1 shows the project location and the following sections describe each option in more detail.

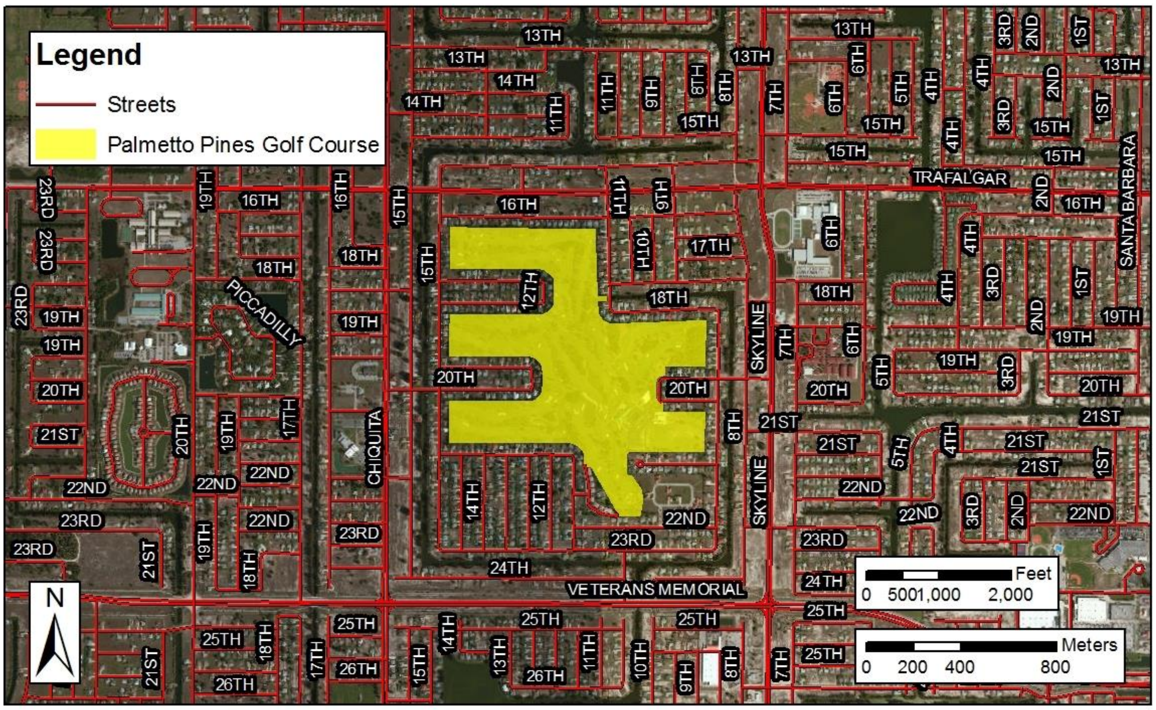


Figure A.1-1. Location of Palmetto Pines Golf Course

Existing Operations

Palmetto Pines Golf Course currently maintains six interconnected freshwater ponds that are usually kept at a control elevation of six feet by pumping water from the City Makai Canal (at the corner of SW 18th Terrace and SW 11th Ave). The golf course has a permit from the South Florida Water Management District to draw 119 million gallons per year or 16.0511 million gallons in any one month. The control depth of six feet currently provides about 10 days of water supply for irrigation before the canal is tapped again. Water quality improves due to the settling time in these ponds, and a "Gridbee" submersible circulation unit, installed in the irrigation pump pond, adds additional treatment by destroying surface algae. The existing pond configuration and flow paths are shown in Figure A.1-2.

Figure A.1-2. Palmetto Pines Golf Course Ponds and Flow Paths

Option #1 - Proposed Pond Retrofits

The configuration of the existing pond system appears to have sufficient capacity to increase the control depth from 6 feet to 7 feet. In addition, the southeast pond appears to have sufficient capacity to increase the control depth to 8 feet. Grading to increase the storage capacity within the ponds should not be required based on the existing pond contours and site reconnaissance. The increase in pond elevation would result in a greater amount of storage for the golf course while also providing treatment for a larger volume of canal water. Costs associated with this option should be negligible, however, approval from the SFWMD would be required if additional canal water is pumped from the canal(s) which may require a special study.

Option #2 - New Pump

There is a possibility that a new pump could be installed near the northwest part of the golf course to bring water via pipe or bioswale to the enhanced ponds. This operation would likely enhance the treatment capabilities of the system because the canal on the west side has higher concentrations of total nitrogen because it drains a much larger portion of the City than the canal on the east side. For this option, the costs were determined based on the assumption that the water would be piped below ground for about 1,500 feet to connect with the pond system. This estimate is highly variable and the final cost is very likely to be different than the estimates provided here. Several factors will affect the cost including: pipe length, the possible use of swales instead of pipe, and whether the golf course can install the system themselves. Also, the cost of the pump(s) will likely vary considerably based on the quality, size, and pumping capacity required. Each of these should be more accurately determined in the final design.

Option #3 - Bioswales

Option three includes 1 to 3 bioswales to treat runoff from the golf course and surrounding areas. In addition, the two southern most bioswales are strategically located to improve drainage for flooding issues. The top most bioswale could be used to convey water from the new pump concept should that option be selected. All three drain directly into the pond system, thereby creating a treatment train for water quality improvements. The costs for bioswales included in this concept plan assume all three bioswales are constructed and landscaped by others than the golf course. Should the golf course construct, or provide the landscaping themselves, the total cost for the bioswale concepts can be considerably less.

Bioswale Soil Media

If bioswales are selected, they should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material,

toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.

- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.1-1.

Table A.1-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	• Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) • Cation Exchange Capacity (CEC) greater than 10 • Soil pH between 5.5 and 7.0 • Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Bioswale Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Bioswale Underdrain

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioswale system fully drains within 72 hours or less.

Bioswale Plant Selection

For the bioswales to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.

- It is recommended that a minimum of three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.1-2.

Table A.1-2. Plant Species for Bioswales

Common name	Scientific Name	Spacing	Container Size	Light
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Enhanced Ponds, Pumps, and Bioswales - Operations and Maintenance

In order to maximize the water quality benefits of the enhanced pond system concept, operations within the golf course will likely need to be modified. With a ten day residence time, the volume of water pumped from the canal will likely need to be increased from 119.1 million gallons per year to more than 220 million gallons. However, a more thorough analysis is required to determine an exact volume. The final decision will depend on irrigation needs, golf course operations, weather, and requirements/approval from the Southwest Florida Water Management District.

Maintenance activities for the ponds, pumps, and bioswales should be focused on the major system components, especially inflow and outlets. Table A.1-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

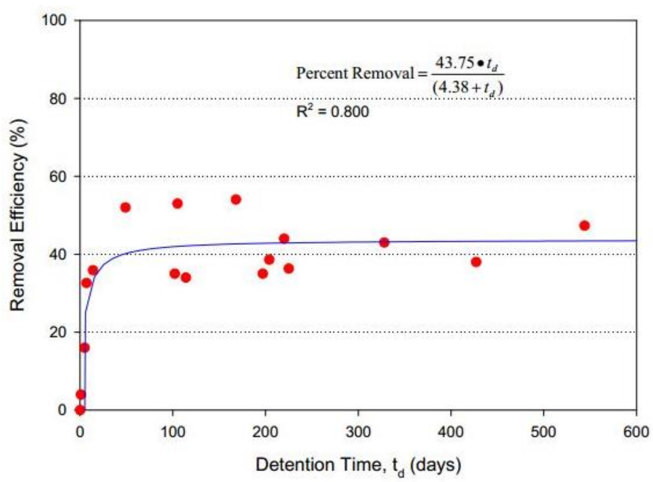
Table A.1-3. Maintenance Tasks for Bioswales

Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Check and repair eroded areas	1 time/year	Eroding banks can reduce the capacity of the swale.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.

Outlet inspection	1 time/year	Check for erosion at the outlet and remove any accumulated sediment.
Miscellaneous upkeep	1 time/year	Tasks include trash and debris collection, plant health, spot weeding, and removing sediment.

Enhanced Pond System - Total Nitrogen Load Impacts

Nitrogen removal for the enhanced wet pond system is based on a variety of factors. The most dominant factor is residence time, which is the amount of time water spends in the pond system before exiting. An ideal scenario allows enough time for unwanted constituents to either settle out of the water column, or be removed through natural chemical and biological processes. According to Florida DEP's Stormwater Quality Applicant's Handbook, total nitrogen (TN) removal efficiency can be determined by the following relationship and equation:



Variable t_d represents detention time (residence time). Hydraulic detention time is governed by flow rate, which would be controlled by the pump system(s). The following equation relates flow rate to detention time:

$$t_d = (\phi)*(AxD)/(Q)$$

Variable ϕ, A, D, *and* Q represents the wet pond's soil porosity, area, depth, and flow rate respectively.

For the pond system, a residence time of 10 days was used to calculate the flow and removal efficiency that might be expected. Table A.1-4 and Figure A.1-3 highlight the total annual load reduction for TN.

Table A.1-4. Load Reductions for the Enhanced Pond System

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Total Nitrogen (lbs)	843	587	256	30%

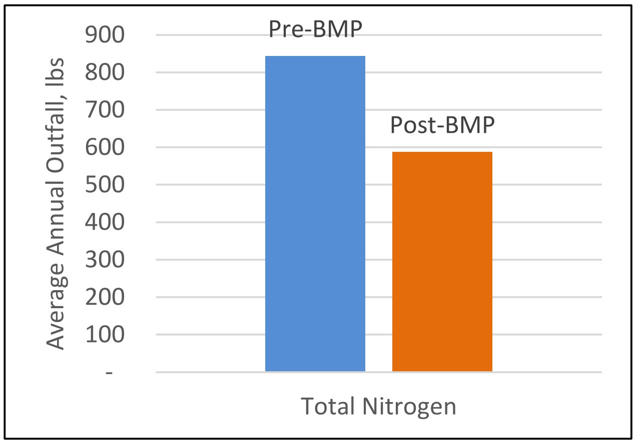


Figure A.1-3. Load Reductions for the Enhanced Pond System

Bioswales - Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing bioswales. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.1-5 and Figure A.1-4 highlight the total annual load reduction for TN. Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration and through improved nutrient absorption and pollutant uptake from the vegetation within the BMP.

Table A.1-5. Load Reductions for the Bioswales

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Total Nitrogen (lbs)	126	67	58	46%

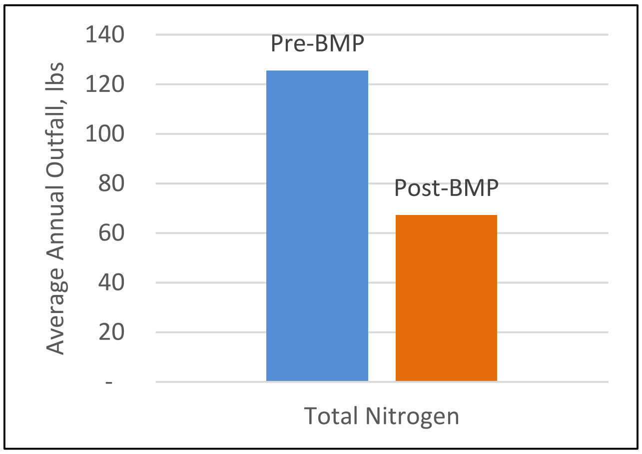


Figure A.1-4. Load Reductions for the Bioswales

Pump and Pipe Cost Opinion

The estimated cost of implementing a new pump and pipe system is presented in Table A.1-6.

These costs are presented for planning purposes only. Actual costs will likely vary from those presented here and are highly dependent on who does the planning, design, construction, and operations and maintenance. As can be seen in the table, the cost for trenching, pipe, and pipe installation constitute the majority of the cost estimate. If the project selects the use of swales in lieu of the pipe, these costs will be significantly lower. These costs are very conservative and as calculated, the cost per pound removed of TN for the new pump and enhanced pond system is estimated to be about $564.45.

Table A.1-6. Pump and Pipe Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Pumping Equipment				
1	Pump	1	Each	$10,000.00	$10,000.00
2	Trenching , Pipe, and Pipe Installation	1,500	LF	$50.00	$75,000.00
	Construction Subtotal				**$85,000.00**
3	Utility Adj (5% of subtotal)				$4,250.00
4	Planning (20% of subtotal)				$17,000.00
5	Design (20% of subtotal)				$17,000.00
6	Mobilization (10% of subtotal)				$8,500.00
7	Contingency (15% of subtotal)				$12,750.00
	Construction Total				**$144,500.00**
8	20-Year O&M	0	SF	$2.28	$0.00
	Total Cost				**$144,500.00**

Bioswales Cost Opinion

The estimated cost of implementing bioswales is presented in Table A.1-7 and assumes the following swale dimensions:

1) Total Length = 1,050
2) Top Width = 12 feet
3) Bottom Width = 6 feet
4) Swale Depth = 1.5 feet
5) Soil Media Depth = 1.5 feet
6) Gravel Layer = 0.5 feet

These costs are presented for planning purposes only. Actual costs will likely vary from those presented here and are highly dependent on factors such as who performs the construction, landscaping, design, and operations and maintenance. These costs are therefore very conservative and will likely be much less than what is presented here. The conservative cost per pound removed of TN for the bioswales is estimated to be about $4,190.94.

Table A.1-7. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	5,100	LF	$2.50	$12,750.00
2	Silt Fence	5,100	LF	$3.00	$15,300.00
	Site Preparation				
3	Excavation and Removal	2,400	CY	$8.52	$20,448.00
	Bioswales				
4	4 inch Perforated Pipe	2,550	LF	$2.00	$5,100.00
5	Gravel Subbase - 6 inches	15,300	SF	$0.55	$8,415.00
6	Fine Grading	30,600	SF	$0.72	$22,032.00
7	Soil Amendments	200	CY	$13.00	$2,600.00
	Landscaping				
8	Vegetation	30,600	SF	$0.50	$15,300.00
Construction Subtotal					**$101,945.00**
9	Utility Adj (5% of subtotal)				$5,097.25
10	Planning (10% of subtotal)				$10,194.50
11	Design (30% of subtotal)				$30,583.50
12	Mobilization (10% of subtotal)				$10,194.50
13	Contingency (15% of subtotal)				$15,291.75
Construction Total					**$173,306.50**
14	20-Year O&M	30,600	SF	$2.28	$69,768.00
Total Cost					**$243,074.50**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.1

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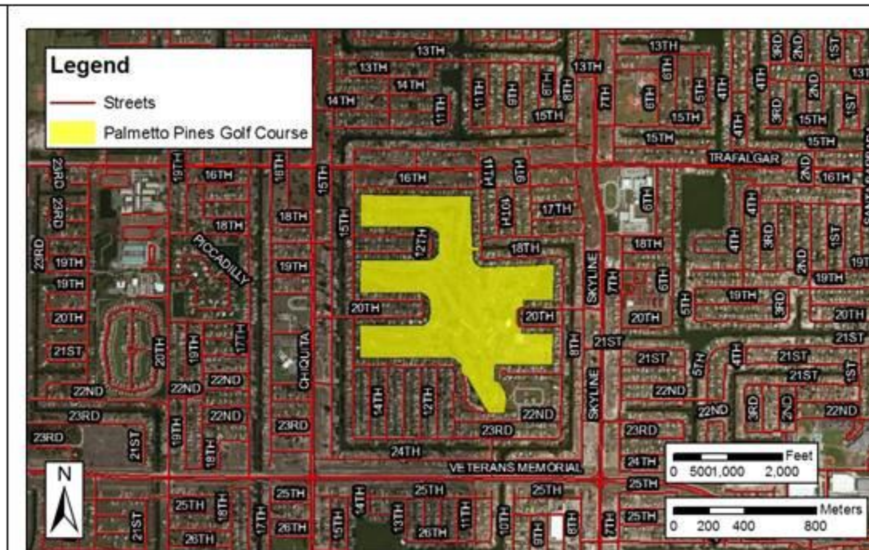
CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: PALMETTO PINES GOLF COURSE



Project Narrative

Option #1 - Proposed Pond Retrofits:
The configuration of the existing pond system appears to have sufficient capacity to increase the control depth from six feet to seven feet. In addition, the southeast pond appears to have sufficient capacity to increase the control depth to eight feet. Grading for these pond retrofits would not be required, as determined by site visits. The increase in pond elevation would result in a greater amount of storage for the golf course while also providing treatment for a larger volume of canal water.
Option #2 – New Pump:
There is a possibility that a new pump could be installed in the northwest part of the golf course to bring water via pipe or bioswale to the enhanced ponds. This operation would likely enhance the treatment capabilities of the system because the canal on the west side drains a much larger portion of the City than the canal on the east side.
Option #3 – Bioswales:
Option three includes three bioswales to treat runoff from the golf course and surrounding areas. In addition, the two southern most bioswales are strategically located to improve drainage for flooding issues. All three drain directly into the pond system, thereby creating a treatment train for water quality improvements.

Site ID	Golf Course	**Latitude**	City-wide
Project Name	Palmetto Pines	**Longitude**	City-wide
Date of Field Visit	3/18/2015	**Street Address**	Multiple
Field Visit Personnel	DS, EB	**Landowner**	City of Cape Coral

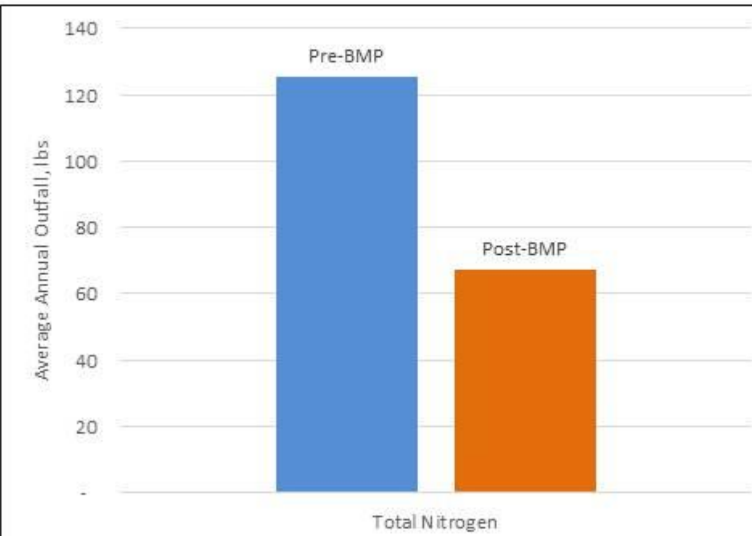
Example Bioswale Cross Section

TETRA TECH

EXHIBIT A.1

Bioswale TN Reductions

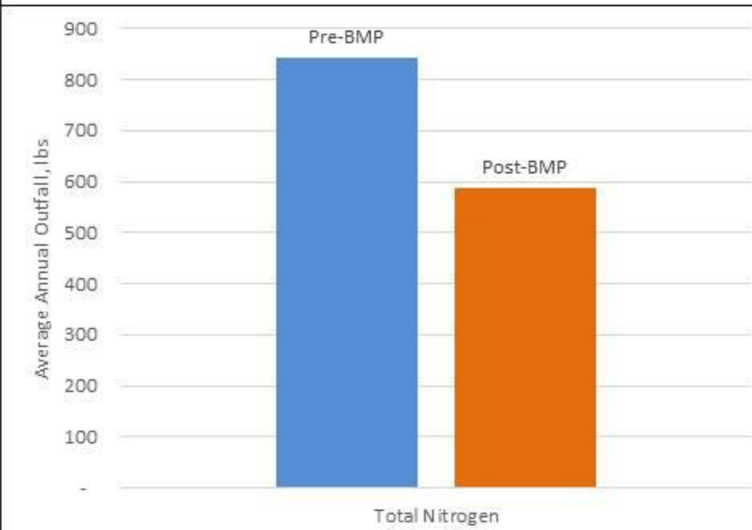
Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Total Nitrogen, (lbs)	126	67	58	46%



Bioswale 1

Wet Pond TN Reductions

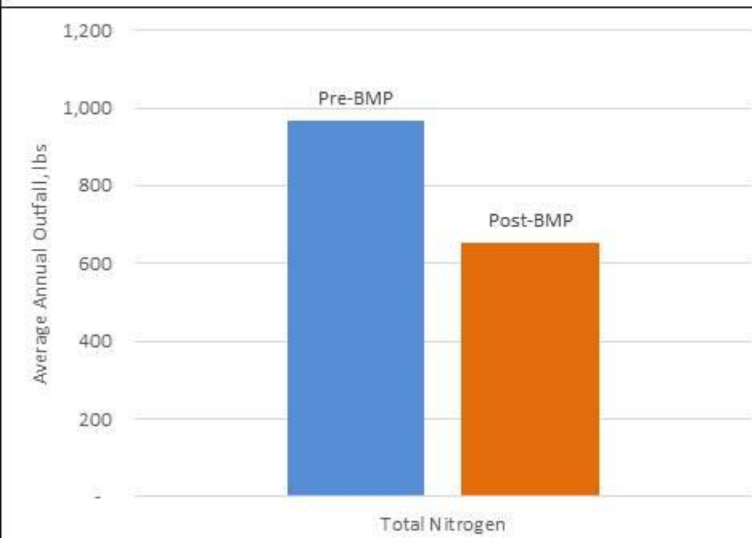
Constituent	Average Annual Loads per acre		Average Annual Reduction per acre	
	Pre-BMP	Post-BMP	Reduction	Percent
Total Nitrogen, (lbs)	843	587	256	30%



Bioswale 2

Total reductions resulting from proposed retrofits

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Total Nitrogen, (lbs)	969	654	314	32%



Bioswale 3

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: PALMETTO PINES GOLF COURSE

TETRA TECH

EXHIBIT A.1

2. P1-1042: SE 10th Place Parking Lot - Bioretention Retrofit

Project Location and Description

The project is located in the City owned parking lot at SE 10th Place between SE 46th Lane and SE 47th Terrace. There are several businesses and facilities surrounding the parking lot including the Fraternal Order of Eagles, Elks Lodge, La Terraza 47, Dixie Roudhouse, Cape Coral Bingo, Back Streets Sports Bar, Salon at Club Square, La Venezia Ballroom, and Team Aubuchon. Figure A.2-1 shows the project location.

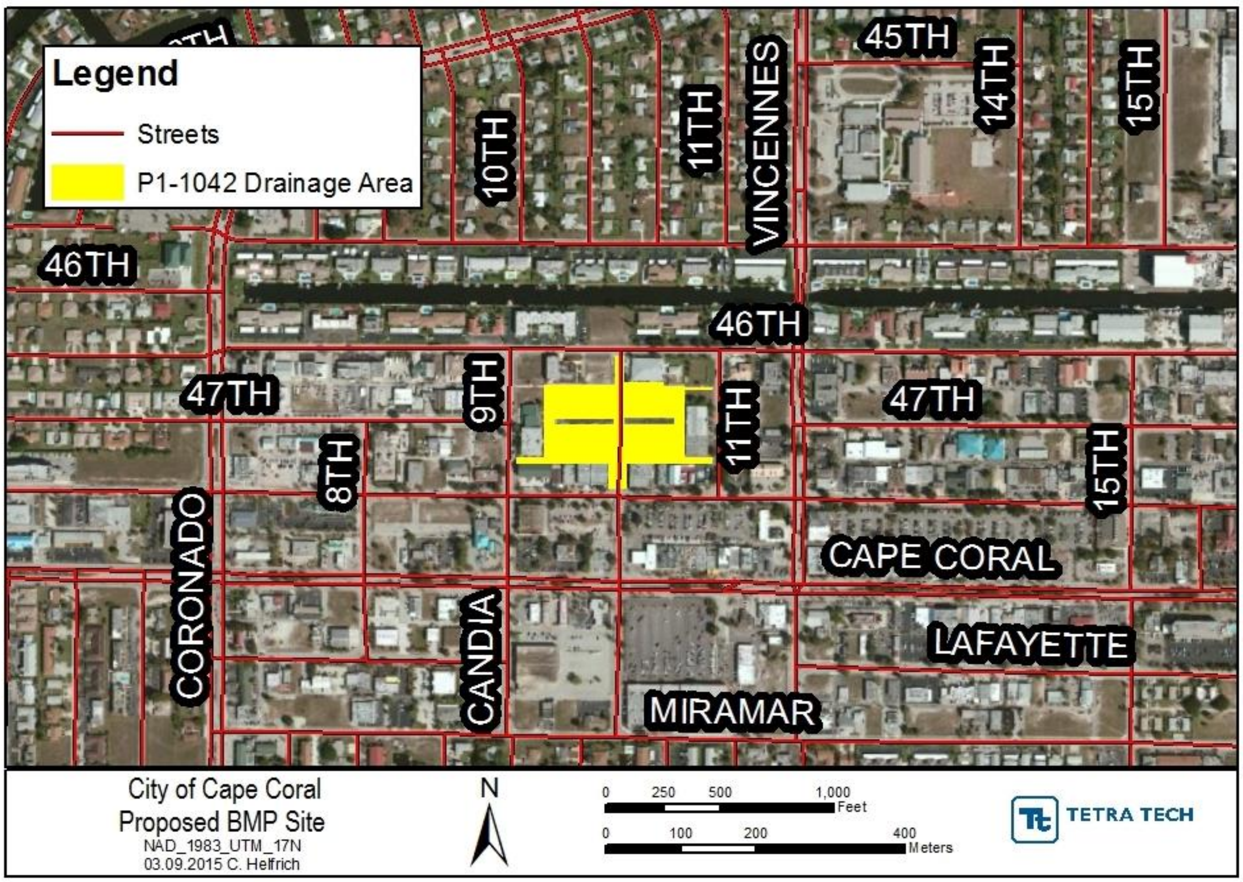


Figure A.2-1. Project location for site P1-1042

This project proposes replacing the existing grass medians in the parking lot with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for the City, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here.

The total contributing drainage area is approximately 5.3 acres and encompasses the entire parking lot on the East and West side of SE 10th Place. The parking lots are graded to direct flow towards the grass medians and then into stormwater pipes that flow East to West as shown in Figure A.2-2.

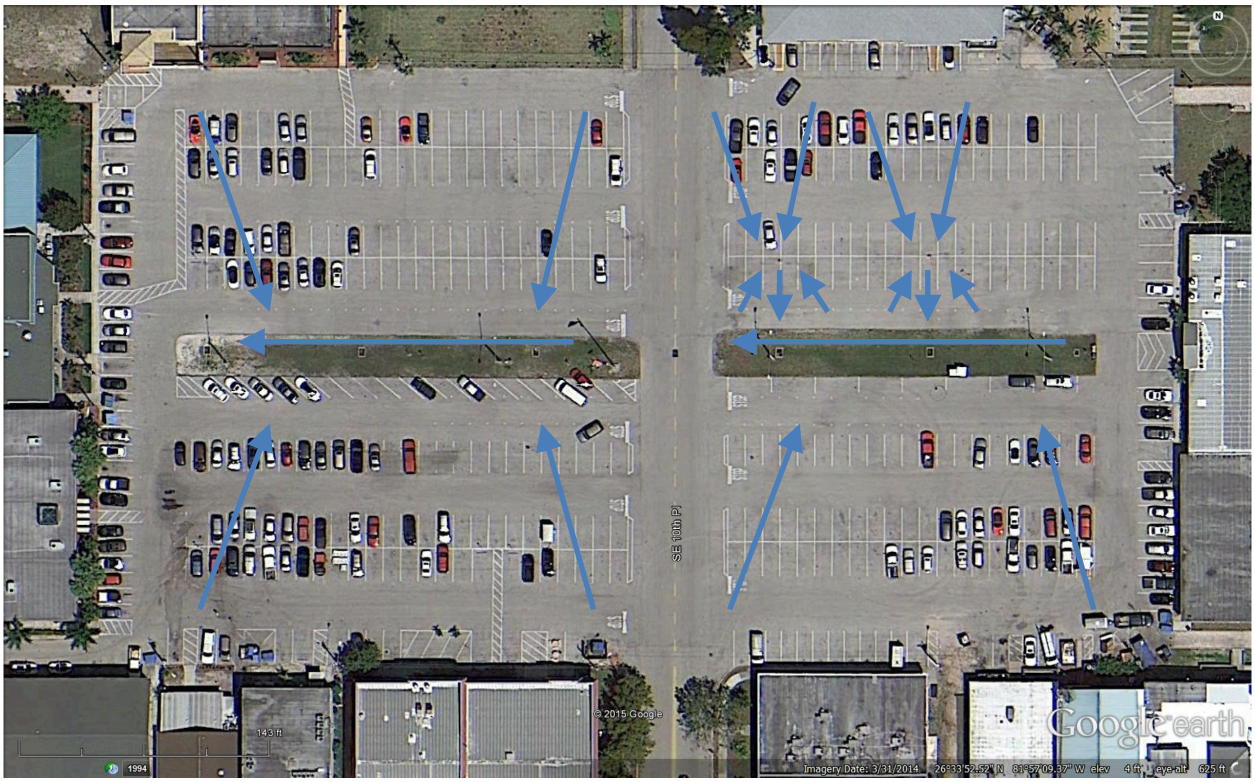


Figure A.2-2. Existing drainage pattern for site P1-1042

BMP Sizing

As a general guideline, bioretention should occupy at least 5 to 7 percent of the drainage area to treat the first inch of runoff (first flush). Other guidance, such as that provided by EPA, recommends that bioretention treat the 85th to 95th percentile storm event which for the City was calculated to be about 1.27 to 2.19 inches respectively. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. For this project, the area available for bioretention represents about 5.14 percent of the drainage area. Thus, the suggested retrofit configuration of the area available for bioretention should be considered adequate for cost effective treatment.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert the existing catch basin/grass areas into bioretention cells in order to capture concentrated sheet flow from the East and West parking lots for treatment. The location utilizes the existing drainage patterns and is configured "on-line" to minimize excavation, grading, demolition, and piping. The BMP configuration and typical cross-section details are provided in Exhibit A.1.

Overflow Structure

During on-line flow all runoff from the drainage area flows into the bioretention system. Flows that exceed the design capacity exit the bioretention area via an overflow structure or weir. The following considerations should be included in the final overflow design:

- The overflow device must convey runoff to the storm sewer.
- Common overflow systems within bioretention consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically between 6 to 12 inches above the surface of the filter bed.
- The overflow device should be scaled to the application.
- At least 3 to 6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.

Soil Media

The bioretention cells should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.2-1.

Table A.2-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	• Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) • Cation Exchange Capacity (CEC) greater than 10 • Soil pH between 5.5 and 7.0 • Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioretention system fully drains within 72 hours or less.

Plant Selection

For the bioretention cells to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
- It is recommended that a minimum of three tree, three shrub, and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.2-2.

Table A.2-2. Plant Species for Bioretention

Common name	Scientific Name	Spacing	Container Size	Light
Dahoon holly	Ilex cassine	10' O.C.	3 gal	full sun to partial shade
Cabbage palm	Sabal palmetto	10' O.C.	3 gal	full sun to partial shade
Wax myrtle	Myrica cerifera	5' O.C.	1 gal	full sun to partial shade
Shyny lyonia	lyonia lucida	5' O.C.	1 gal	full sun to partial shade
Dwarf yaupon holly	Ilex vomitoria cv.Schellings	5' O.C.	1 gal	part shade/part sun
Saw palmetto	Serenoa repens	5' O.C.	3 gal	full sun to full shade
American beautyberry	Callicarpa americana	5' O.C.	1 gal	part shade/part sun
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities for bioretention should be focused on the major system components, especially landscaping and the overflow structures. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the overflow structures consists of regular inspection for clogging.

Irrigation for the bioretention cells might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than non-native plants.

Table A.2-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.2-3. Maintenance Tasks for Bioretention

Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on the location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining 1"-3" uniform mulch layer.
Mulch removal	1 time/2-3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the bioretention BMP. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.2-4 and Figure A.2-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.2-4. SUSTAIN model load reductions for Site P1-1042

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	1,070,050	739,156	330,895	31%
Total Nitrogen (lbs)	311	122	189	61%

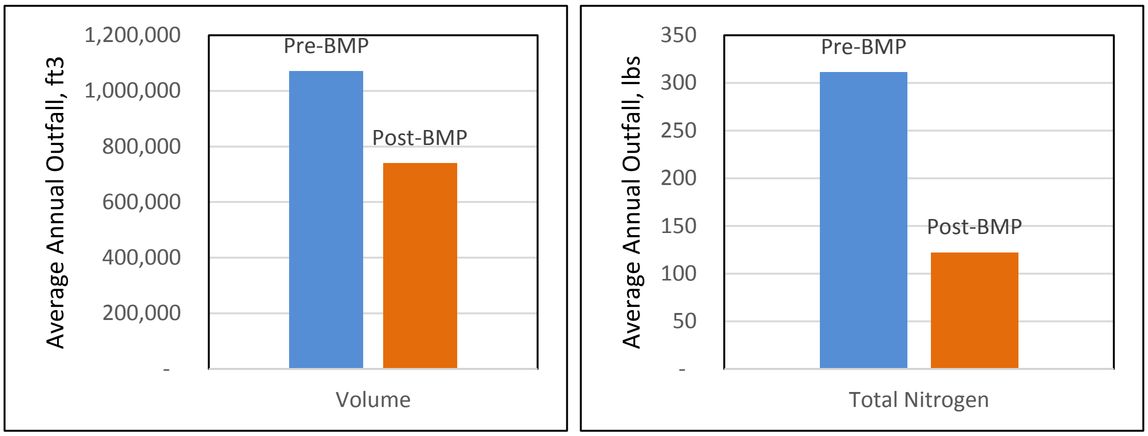


Figure A.2-3. SUSTAIN model load reductions for Site P1-1042

Cost Opinion

The estimated costs of implementing bioretention at the City owned parking lot are presented in Table A.2-5. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $952.00.

Table A.2-5. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	1,000	LF	$2.50	$2,500.00
2	Silt Fence	1,000	LF	$3.00	$3,000.00
	Site Preparation				
3	Excavation and Removal	1,750	CY	$8.52	$14,910.00
	Bioretention				$0.00
4	4 inch Perforated Pipe	1,750	LF	$2.00	$3,500.00
5	Gravel Subbase - 6 inches	12,000	SF	$0.55	$6,600.00
6	Fine Grading	12,000	SF	$0.72	$8,640.00
7	Soil Amendments	200	CY	$13.00	$2,600.00
	Landscaping				
8	Vegetation	12,000	SF	$4.00	$48,000.00
Construction Subtotal					**$89,750.00**
9	Utility Adj (5% of subtotal)				$4,487.50
10	Planning (10% of subtotal)				$8,975.00
11	Design (30% of subtotal)				$26,925.00
12	Mobilization (10% of subtotal)				$8,975.00
13	Contingency (15% of subtotal)				$13,462.50
Construction Total					**$152,575.00**
14	20-Year O&M	12,000	SF	$2.28	$27,360.00
Total Cost					**$179,935.00**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.2.

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1042

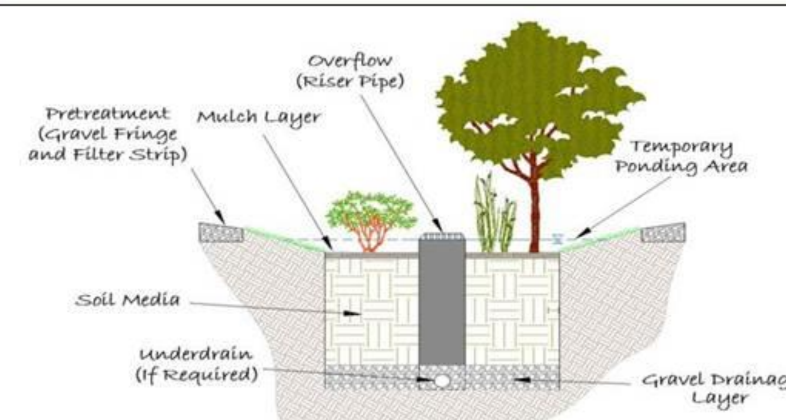
Site Location			
Site ID	P1-1042	Latitude	26° 33' 52.68" N
Project Name	TBD	Longitude	81° 57' 09.07" W
Date of Field Visit	12/08/2014	Street Address	SE 10th Street
Field Visit Personnel	EB, DS	Landowner	City of Cape Coral

Project Narrative

This project proposes replacing the existing grass medians in the parking lot with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for Cape Coral, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here.

Project site, east side of parking lot

Project site, east side of parking lot with proposed Bioretention



Example Bioretention Retrofit Cross Section

TETRA TECH

EXHIBIT A.2

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1042

Project site, west side of parking lot

Project site, west side of parking lot with proposed Bioretention

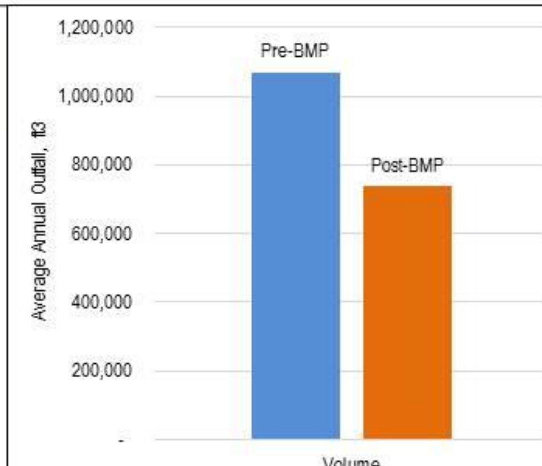
Project site, south entrance to parking lot

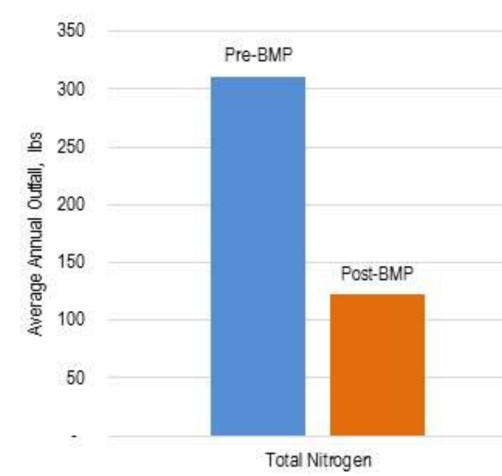
Project site, south entrance to parking lot with proposed Bioretention

Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

Costs	
Planning	$8,975
Design	$26,925
Contingency	$13,462
Mobilization	$8,975
Construction	$89,750
20-year O&M	$27,360
Total Cost	**$179,935**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	1,070,050	739,156	330,895	31%
Total Nitrogen, (lbs)	311	122	189	61%





TETRA TECH

EXHIBIT
A.2

3. Dry Swales

Project Description

This project proposes replacing existing stormwater conveyance channels (grass channels) with dry swales. Most of the multifamily, single family, and low density residential areas in the City utilize grass channels and are good candidates for dry swale retrofits. The retrofit generally includes restoring the capacity of the existing grass channels for stormwater conveyance and adding a pre-mixed soil filter system and underdrain to treat and return the stormwater to the conveyance system further downstream. The dry swale design features will ensure that infiltration of stormwater will not depend only on the infiltration rate and nutrient removal capacity of the existing soils. Only in special circumstances where natural soil and groundwater conditions consistently provide the right soil chemistry and infiltration rates will a traditional drainage/grassed channel design provide the same water quality benefits as a dry swale design.

The dry swale retrofit should consist of a depression filled with 1.5 to 2 feet of engineered soil media, which is covered with either drought/flood tolerant grass or sod. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet for most applications; however, there will be instances in the City where dry swale retrofits will need to include provisions to operate as a wet swale during the wet season because the distance will be less than 0.5 feet (or within the water table itself). One positive of this condition might be improved drainage that will help to reduce flooding during the wet season.

Stormwater drains onto the surface of the dry swale and as the water infiltrates through the soil media, it is drained either into the native soil, or out of the soil media through an underdrain pipe. The dry swale retrofits will generally be designed to provide one or more feet of ponding capacity for rain events. Culverts are provided below driveways for conveyance downstream to the canal system. Because most of the residential areas within the City already use grass channels for stormwater conveyance, retrofitting these channels with dry swales should be easily incorporated into the City's long term stormwater management plan as a cost effective practice.

The contributing drainage area to each swale includes road drainage and runoff from each residential lot where a dry swale will be installed. Runoff from the residential parcels includes rooftop area, driveways, and yards. Figure A.3-1 shows the multifamily, single family, and low density residential areas that should be considered for dry swale retrofits and prioritization.

The costs and costs per pound removed in this concept plan are based on multifamily residential implementation because multifamily residential areas should be prioritized first, followed by single family residential, followed by low density residential.

The AIM/Tetra Tech team encourages the City to consider implementing a pilot program to study the effectiveness of enhanced dry swales at removing TN in the City. The program would enable the City to evaluate different combinations of filter media and other design considerations to determine local removal efficiencies compared to the existing grass channels. In addition, the program will help pinpoint the best overall design for distributed implementation should the concept prove cost effective.

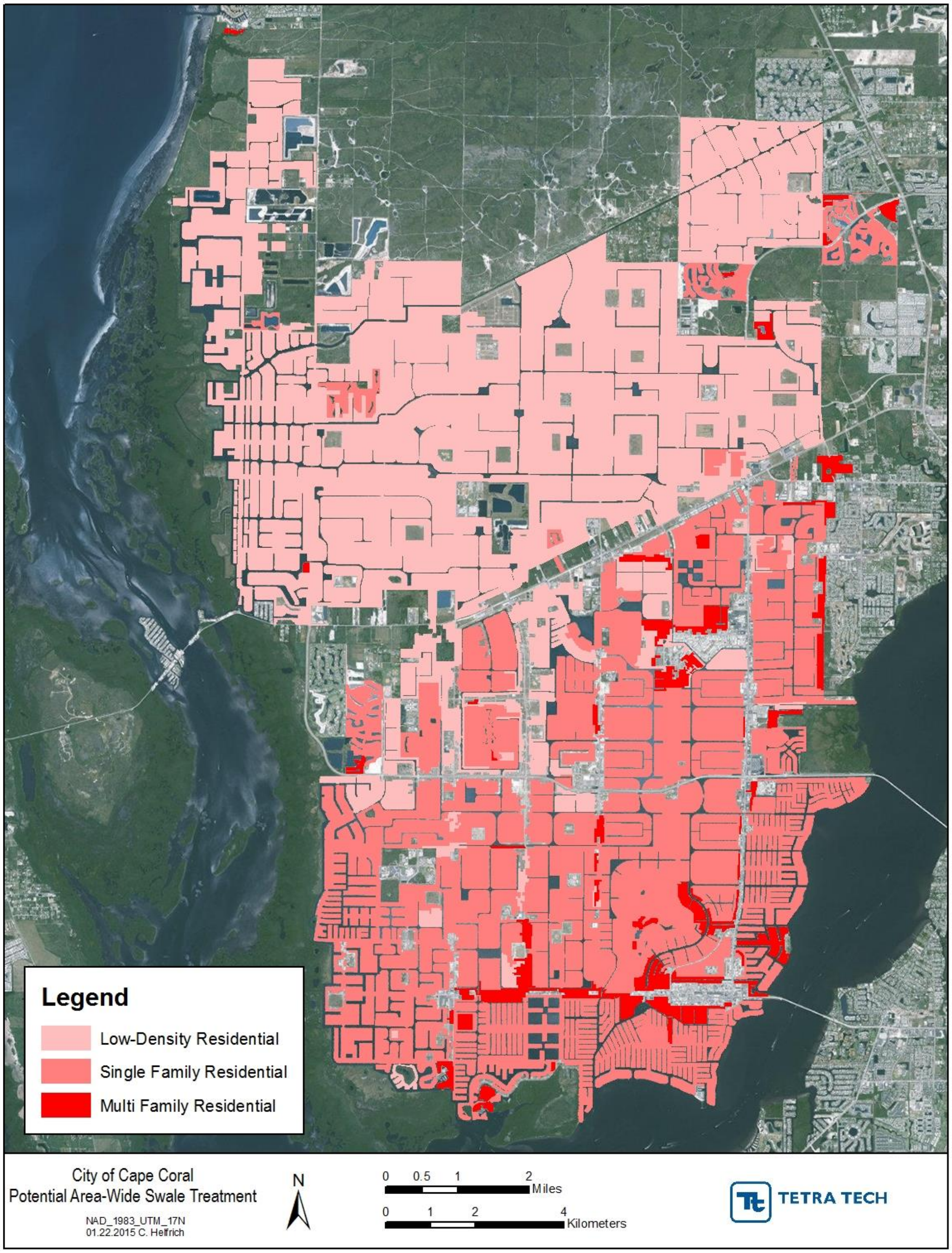


Figure A.3-1. Residential Parcels Where Dry Swale Retrofits are Recommended

BMP Sizing

The maximum contributing drainage area to a dry swale should be less than five acres. Depending on the amount of impervious cover, the footprint should be between 3 and 10 percent of the contributing drainage area. For the residential parcels in the City where dry swales are recommended, it is anticipated that the swale footprint will be about 5 percent of the contributing drainage area. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, drainage capacity, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. Based on the planned implementation strategy of prioritizing residential areas, the area expected to be available for dry swale retrofits is adequate for cost effective treatment.

BMP Conceptual Layout

The suggested dry swale retrofits will generally match the geometry of the existing grass drainage channels with identical lengths and very similar widths and depths. However, depending on the capacity required to minimize flooding, there may be instances where the existing conveyance channel will need to be widened or deepened. Each site or area should be hydrologically/hydraulically evaluated during the design process. A typical dry swale retrofit and typical cross-section details are provided in Exhibit A.2.

Soil Media

The dry swales should be designed to have a soil media and geometry that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 2h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity around 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.3-1.

Table A.3-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	• Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) • Cation Exchange Capacity (CEC) greater than 10 • Soil pH between 5.5 and 7.0 • Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the dry swale system fully drains within 72 hours or less.

Operations and Maintenance

Maintenance activities for the dry swales should be focused on the major system components, especially inflow and outlets. In most cases, landscaped components will be maintained by home owners. However, appropriate fertilizer rates, good mowing practices, and other related maintenance procedures should be discussed with the home owners following construction.

Table A.3-2 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.3-2. Maintenance Tasks for Dry Swales

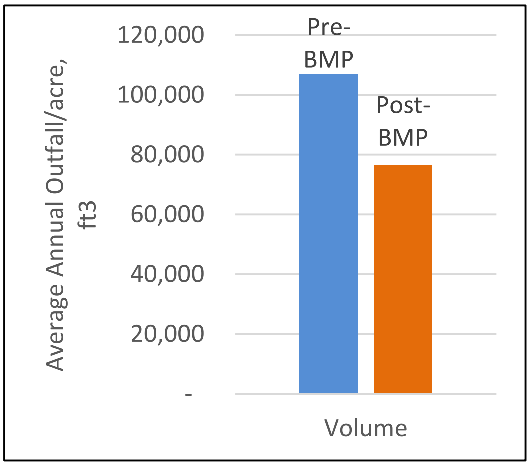
Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Check and repair eroded areas	1 time/year	Eroding banks can reduce the capacity of the swale.
Mowing	As needed	Grass should be mowed to a height of 4"-9"
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Outlet inspection	1 time/year	Check for erosion at the outlet and remove any accumulated sediment.
Miscellaneous upkeep	1 time/year	Tasks include trash and debris collection, plant health, spot weeding, and removing sediment.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing dry swales in multifamily residential areas, single family residential areas, and low density residential areas. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.3-3 and Figure A.3-2 highlight the total annual load reduction for total nitrogen (TN) for each or the multifamily residential classification. Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration and through improved nutrient absorption and pollutant uptake from the vegetation within the BMP.

Table A.3-3. SUSTAIN Model Load Reductions for the Dry Swales for One Acre of Multifamily Residential Treatment

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	107,153	76,623	30,530	28%
Total Nitrogen (lbs)	18	11	7	43%



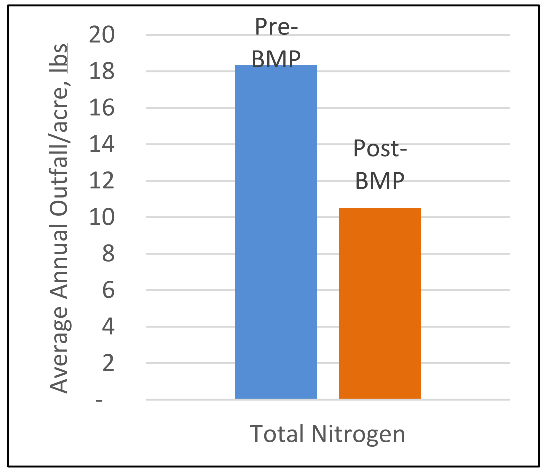


Figure A.3-2. SUSTAIN Model Load Reductions for the Dry Swales for One Acre of Multifamily Residential Treatment

Cost Opinion

The estimated cost of implementing dry swales is presented in Table A.3-4 on a per acre basis and assumes the following swale dimensions:

1) Length = 188 feet
2) Top Width = 12 feet
3) Bottom Width = 6 feet
4) Swale Depth = 1.5 feet
5) Soil Media Depth = 1.5 feet
6) Gravel Layer = 0.5 feet

These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $962.00 per acre for multifamily residential, $2,208.00 per acre for single family residential, and $3,613.00 per acre for low density residential.

Table A.3-4. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Erosion Control	40	LF	$2.50	$100.00
	Site Preparation				
2	Excavation and Removal	84	CY	$8.52	$711.89
	Bioretention				
3	4 inch Perforated Pipe	188	LF	$1.06	$199.28
4	Gravel Subbase - 6 inches	1128	SF	$0.55	$620.40
5	Fine Grading	2444	SF	$0.72	$1,759.68
6	Soil Amendments	5	CY	$13.00	$61.10
	Landscaping				
7	Sod	2444	SF	$0.55	$1,344.20
Construction Subtotal					**$4,796.55**
8	Planning (10% of subtotal)				$479.66
9	Design (5% of subtotal)				$239.83
10	Mobilization (5% of subtotal)				$239.83
11	Contingency (15% of subtotal)				$719.48
Construction Total					**$6,475.35**
12	20-Year O&M	2444	SF	$0.44	$1,075.36
Total Cost					**$7,550.71**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.3.

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CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: CITY-WIDE SWALE TREATMENT

Project Narrative

This project proposes replacing existing stormwater conveyance channels (grass channels) with dry swales. Most of the multifamily, single family, and low density residential areas in the City utilize grass channels and are good candidates for dry swale retrofits. The retrofit generally includes restoring the capacity of the existing grass channels for stormwater conveyance and adding a pre-mixed soil filter system and underdrain to treat and return the stormwater to the conveyance system further downstream. The dry swale design features will ensure that infiltration of stormwater will not depend only on the infiltration rate and nutrient removal capacity of the existing soils. Only in special circumstances where natural soil and groundwater conditions consistently provide the right soil chemistry and infiltration rates will a traditional drainage/grassed channel design provide the same water quality benefits as a dry swale design.

Site Location

Site ID		**Latitude**	City-wide
Project Name	Dry Swales	**Longitude**	City-wide
Date of Field Visit	N/A	**Street Address**	Multiple
Field Visit Personnel	N/A	**Landowner**	City of Cape Coral

Example Project site, 5th Place SE facing north

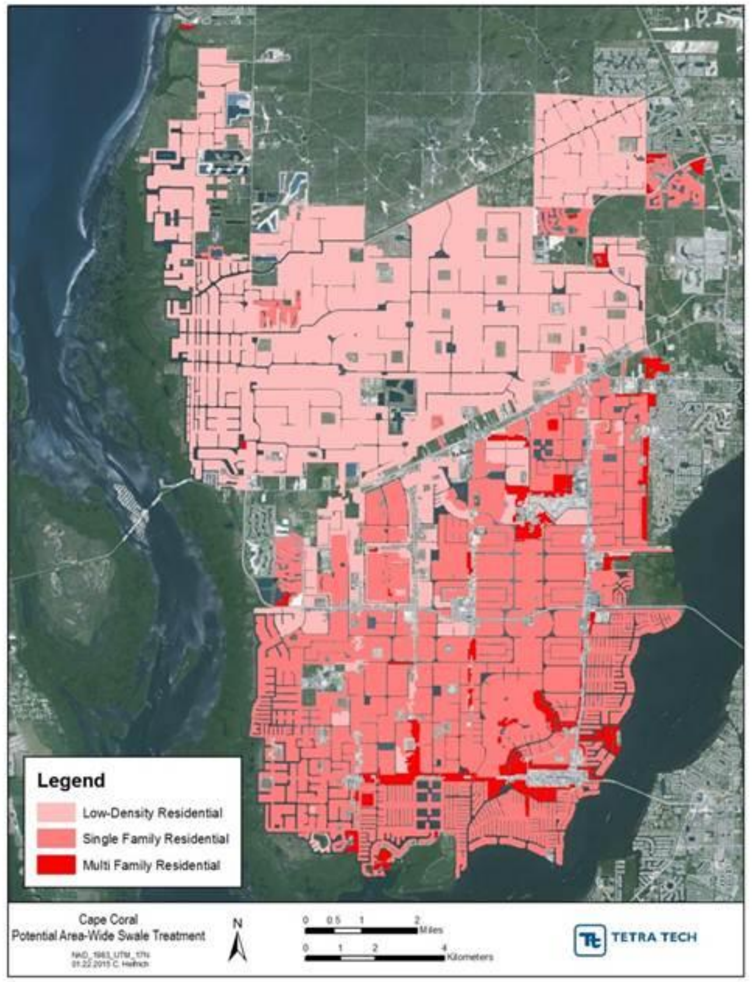
Example Project site, 5th Place SE facing north with proposed vegetated swake

Example Vegetated Swale Cross Section

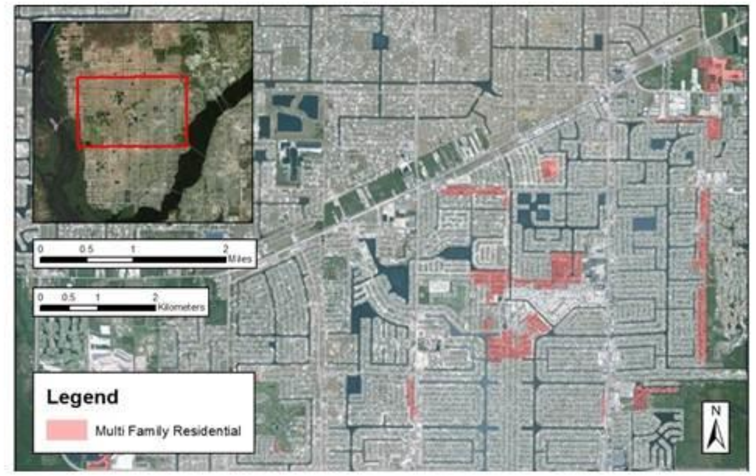
TETRA TECH

EXHIBIT A.3

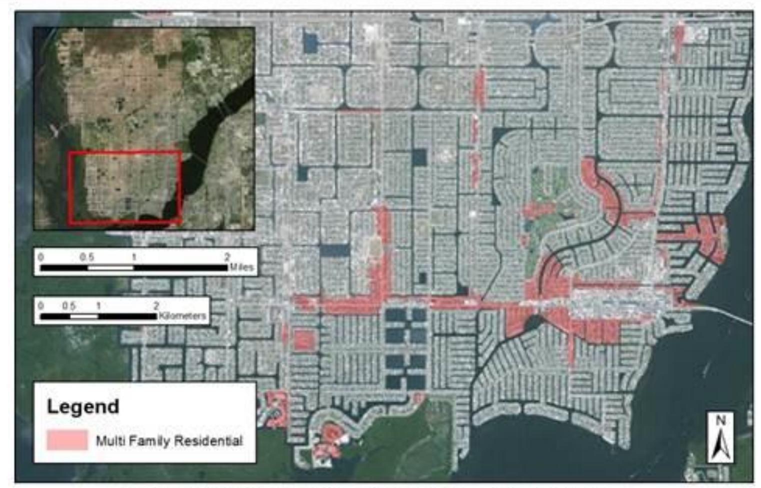
CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: CITY-WIDE SWALE TREATMENT



City of Cape Coral residential zoning overview



Mullti Family Residential focus areas, northern parcels

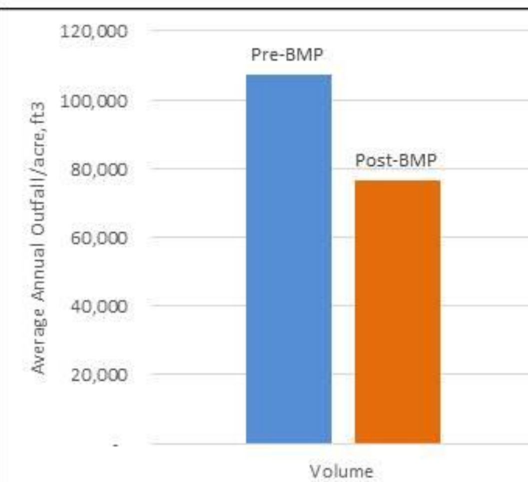


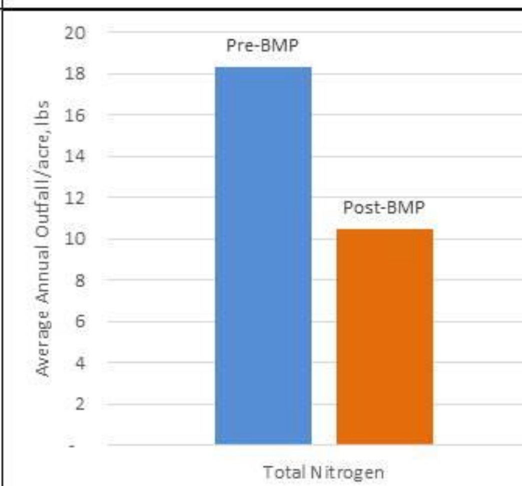
Mullti Family Residential focus areas, southern parcels

Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

Planning	$480
Design	$240
Contingency	$719
Mobilization	$240
Construction	$4,797
20-year O&M	$1,075
Total Cost	**$7,550**

Constituent	Average Annual Loads per acre		Average Annual Reduction per acre	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	107,153	76,623	30,530	28%
Total Nitrogen, (lbs)	18	11	8	43%





TETRA TECH

EXHIBIT A.3

4. P1-1034: Del Prado Mall - Parking Lot Retrofit

Project Location and Description

The project is located in the City owned parking lot of Del Prado Mall directly off of Del Prado Blvd. There are several businesses and facilities surrounding the parking lot including TJ-Max, Planet Fitness, Aaron's, Cici's Pizza, Factory Card Outlet, and Party City. Figure A.4-1 shows the project location.

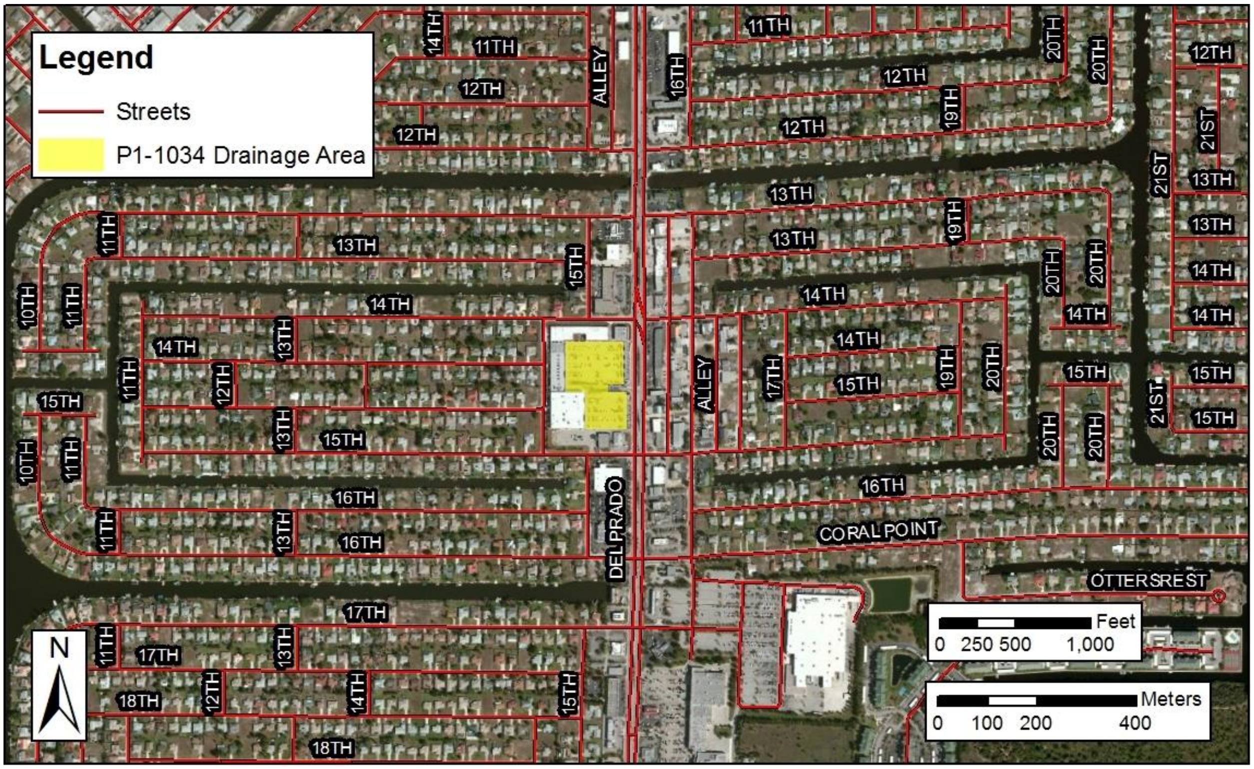


Figure A.4-1. Project Location for Site P1-1034

This project proposes replacing the portions of the existing parking lot with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for the City, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here.

The total contributing drainage area is approximately 4.5 acres and encompasses all the parking lots of Del Prado Mall. The parking lots are graded to direct flow towards the east end and then into stormwater pipes as shown in the Figure A.4-2.

Figure A.4-2. Existing Drainage Patterns for Site P1-1034

BMP Sizing

As a general guideline, bioretention should occupy at least 5 to 7 percent of the drainage area to treat the first inch of runoff (first flush). Other guidance, such as that provided by EPA, recommends that bioretention treat the 85^{th} to 95^{th} percentile storm event which for the City was calculated to be about 1.27 to 2.19 inches respectively. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. For this project, the area available for bioretention represents about 6.68 percent of the drainage area. Thus, the suggested retrofit configuration of the area available for bioretention should be considered adequate for cost effective treatment.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert portions of the existing parking lot into bioretention in order to capture concentrated flow from the parking lot for treatment. The location utilizes the existing drainage patterns and is configured "on-line" to minimize excavation, grading, demolition, and piping. The BMP configuration and typical cross-section details are provided in Exhibit A.3.

Overflow Structure

During on-line flow all runoff from the drainage area flows into the bioretention system. Flows that exceed the design capacity exit the bioretention area via an overflow structure or weir. The following considerations should be included in the final overflow design:

- The overflow device must convey runoff to the storm sewer.
- Common overflow systems within bioretention consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically between 6 to 12 inches above the surface of the filter bed.
- The overflow device should be scaled to the application.
- At least 3 to 6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.

Soil Media

The bioretention cells should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.4-1.

Table A.4-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	• Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) • Cation Exchange Capacity (CEC) greater than 10 • Soil pH between 5.5 and 7.0 • Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioretention system fully drains within 72 hours or less.

Plant Selection

For the bioretention cells to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
- It is recommended that a minimum of three tree, three shrub, and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.4-2.

Table A.4-2. Plant Species for Bioretention

Common name	Scientific Name	Spacing	Container Size	Light
Dahoon holly	Ilex cassine	10' O.C.	3 gal	full sun to partial shade
Cabbage palm	Sabal palmetto	10' O.C.	3 gal	full sun to partial shade
Wax myrtle	Myrica cerifera	5' O.C.	1 gal	full sun to partial shade
Shyny lyonia	lyonia lucida	5' O.C.	1 gal	full sun to partial shade
Dwarf yaupon holly	Ilex vomitoria cv.Schellings	5' O.C.	1 gal	part shade/part sun
Saw palmetto	Serenoa repens	5' O.C.	3 gal	full sun to full shade
American beautyberry	Callicarpa americana	5' O.C.	1 gal	part shade/part sun
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities should be focused on the major system components, especially landscaping and the overflow structures. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the overflow structures consists of regular inspection for clogging.

Irrigation for the bioretention cells might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than non-native plants.

Table A.4-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.4-3. Maintenance Tasks for Bioretention

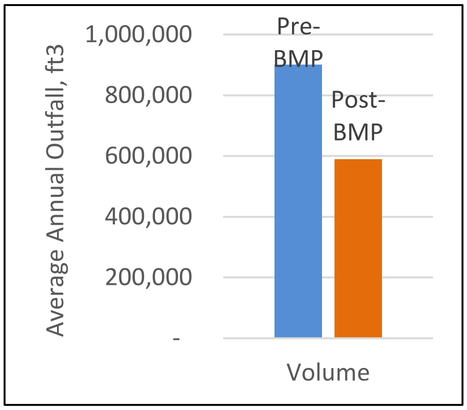
Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on the location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining 1"-3" uniform mulch layer.
Mulch removal	1 time/2-3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the bioretention BMP. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.4-4 and Figure A.4-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.4-4. SUSTAIN Model Load Reductions for Site P1-1034

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	901,176	588,618	312,558	35%
Total Nitrogen (lbs)	279	104	175	63%



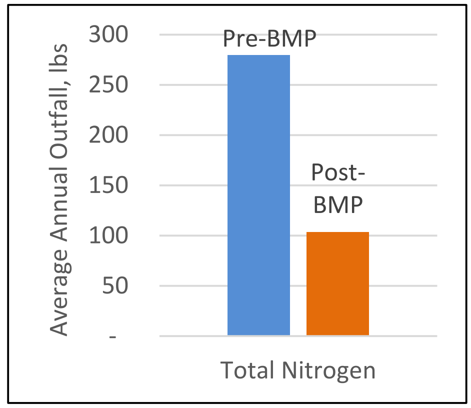


Figure A.4-3. SUSTAIN Model Load Reductions for Site P1-1034

Cost Opinion

The estimated costs of implementing bioretention at the City owned parking lot are presented in Table A.4-5. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $1,065.00.

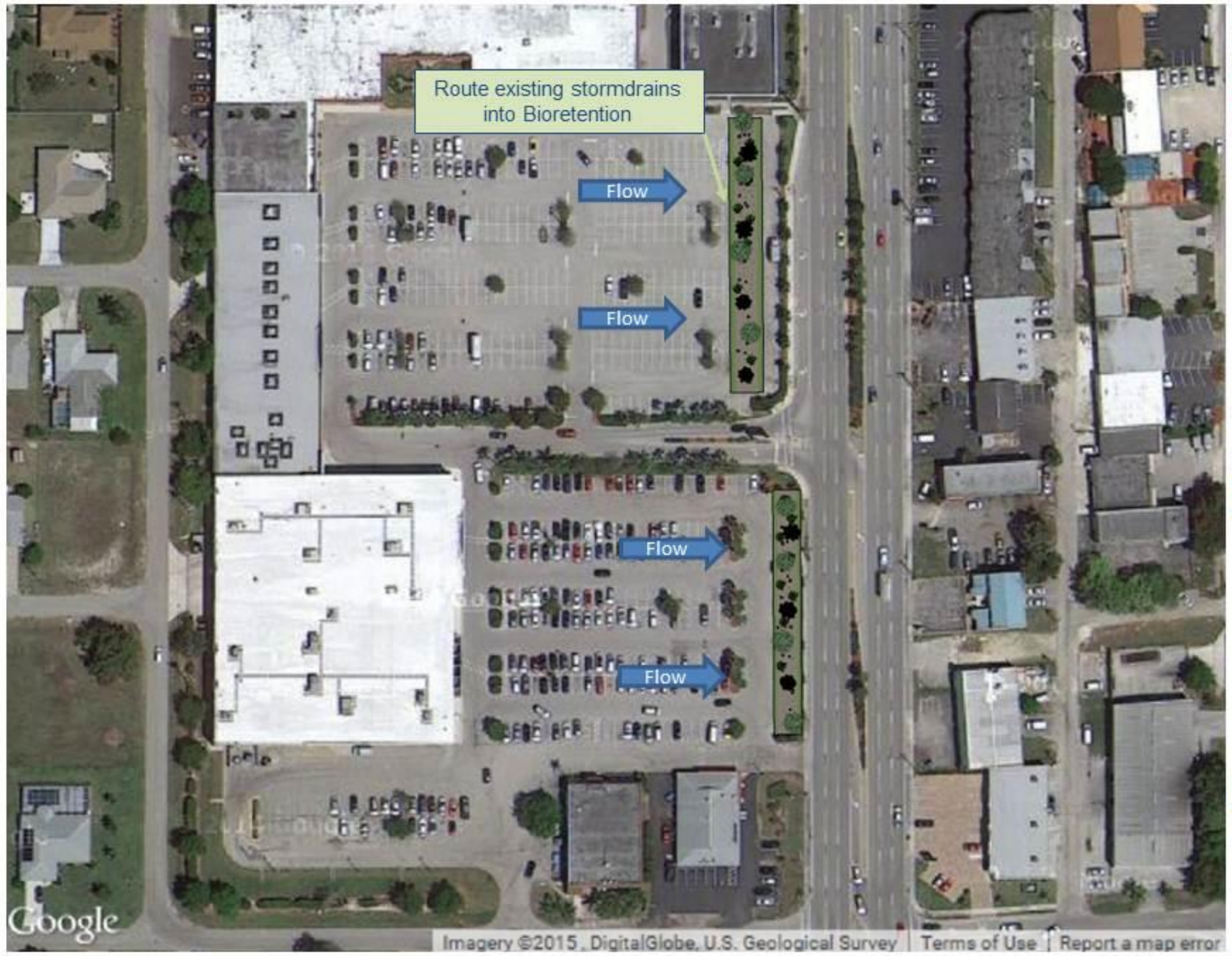
Table A.4-5. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	1130	LF	$2.50	$2,825.00
2	Silt Fence	1130	LF	$3.00	$3,390.00
	Site Preparation				
3	Excavation and Removal	1900	CY	$8.52	$16,188.00
	Bioretention				
4	4 inch Perforated Pipe	1660	LF	$2.00	$3,320.00
5	Gravel Subbase - 6 inches	13000	SF	$0.55	$7,150.00
6	Fine Grading	13000	SF	$0.72	$9,360.00
7	Soil Amendments	240	CY	$13.00	$3,120.00
	Landscaping				
8	Vegetation	13000	SF	$4.00	$52,000.00
Construction Subtotal					**$97,353.00**
9	Utility Adj (5% of subtotal)				$4,867.65
10	Planning (10% of subtotal)				$9,735.30
11	Design (30% of subtotal)				$29,205.90
12	Mobilization (10% of subtotal)				$9,735.30
13	Contingency (20% of subtotal)				$19,470.60
Construction Total					**$170,367.75**
14	20-Year O&M	7500	SF	$2.28	$17,100.00
Total Cost					**$187,467.75**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.4.

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1034

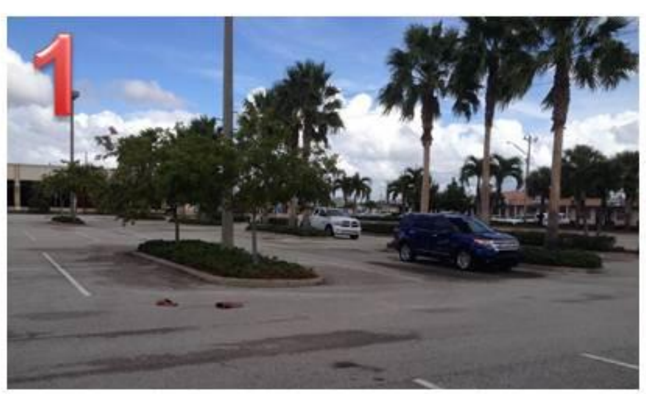


Project Narrative

This project proposes replacing the portions of the existing parking lot with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for Cape Coral, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here.

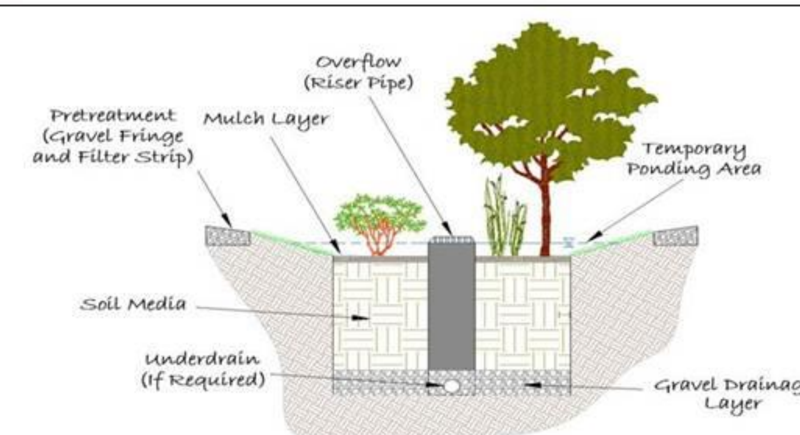
Site Location

Site ID	P1-1034	**Latitude**	26° 37' 30.85" N
Project Name	TBD	**Longitude**	81° 56' 29.35" W
Date of Field Visit	12/02/2014	**Street Address**	Del Prado Boulevard
Field Visit Personnel	EB, DS	**Landowner**	City of Cape Coral



Project site, northern parking lot facing Del Prado Blvd

Project site, northern parking lot facing Del Prado Blvd with proposed Bioretention



Example Bioretention Retrofit Cross Section

TETRA TECH

EXHIBIT A.4

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1034

Project site, southern parking lot from Del Prado Blvd

Project site, southern parking lot from Del Prado Blvd with proposed Bioretention

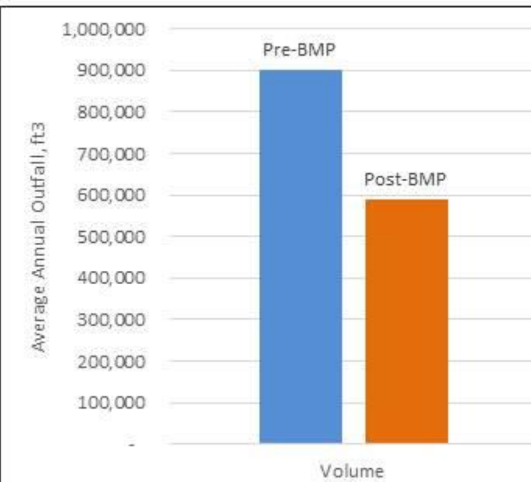
Project site, southern parking lot facing Del Prado Blvd

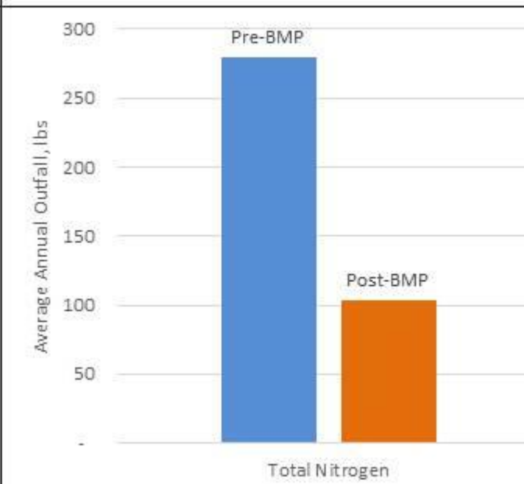
Project site, southern parking lot facing Del Prado Blvd with proposed Bioretention

Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

Planning	$9,735
Design	$29,206
Contingency	$19,470
Mobilization	$9,735
Construction	$97,353
20-year O&M	$17,100
Total Cost	**$187,468**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	901,176	588,618	312,558	35%
Total Nitrogen, (lbs)	279	104	176	63%





TETRA TECH

EXHIBIT A.4

5. P1-1031: Cape Coral Sports Center - Detention Basin Retrofit

Project Location and Description

The project is located in the City owned detention basin at the Cape Coral Sports Center. This facility includes four baseball fields, five softball fields, and a playground. Figure A.5-1 shows the project location and drainage area.

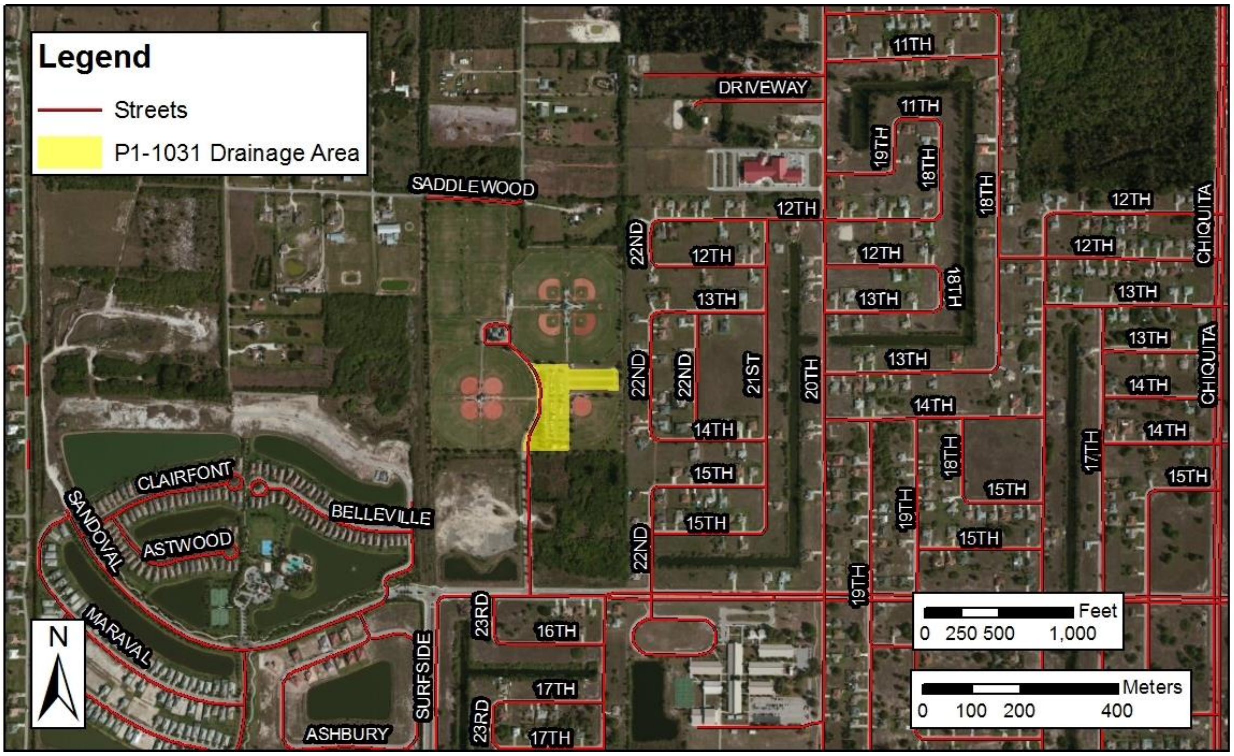


Figure A.5-1. Project Location for Site P1-1031

This project proposes replacing the existing detention basin with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for the City, and in this case presents an excellent opportunity as a retrofit of an existing detention basin.

The total contributing drainage area is approximately 4.4 acres and includes the entire parking area for the Cape Coral Sports Center. The parking lots are graded to direct flow towards swales as shown in theFigure A.5-2.

Figure A.5-2. Existing Drainage Patterns for Site P1-1031

BMP Sizing

As a general guideline, bioretention should occupy at least 5 to 7 percent of the drainage area to treat the first inch of runoff (first flush). Other guidance, such as that provided by EPA, recommends that bioretention treat the 85^{th} to 95^{th} percentile storm event which for the City was calculated to be about 1.27 to 2.19 inches respectively. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. For this project, the area available for bioretention represents about 4.4 percent of the drainage area, but could also be increased in size if required. Thus, the suggested retrofit configuration of the area available for bioretention should be considered adequate for cost effective treatment.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert the existing detention basin into bioretention in order to capture concentrated sheet flow from the facilities parking lots for treatment. The location utilizes the existing drainage patterns and is configured "on-line" to minimize excavation, grading, demolition, and piping. The BMP configuration and typical cross-section details are provided in Exhibit A.5.

Overflow Structure

During on-line flow all runoff from the drainage area flows into the bioretention system. Flows that exceed the design capacity exit the bioretention area via an overflow structure or weir. The following considerations should be included in the final overflow design:

- The overflow device must convey runoff to the storm sewer.
- Common overflow systems within bioretention consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically between 6 to 12 inches above the surface of the filter bed.
- The overflow device should be scaled to the application.
- At least 3 to 6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.

Soil Media

The bioretention cells should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.5-1.

Table A.5-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	• Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) • Cation Exchange Capacity (CEC) greater than 10 • Soil pH between 5.5 and 7.0 • Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioretention system fully drains within 72 hours or less.

Plant Selection

For the bioretention cells to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
- It is recommended that a minimum of three tree, three shrub, and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.5-2.

Table A.5-2. Plant Species for Bioretention

Common name	Scientific Name	Spacing	Container Size	Light
Dahoon holly	Ilex cassine	10' O.C.	3 gal	full sun to partial shade
Cabbage palm	Sabal palmetto	10' O.C.	3 gal	full sun to partial shade
Wax myrtle	Myrica cerifera	5' O.C.	1 gal	full sun to partial shade
Shyny lyonia	lyonia lucida	5' O.C.	1 gal	full sun to partial shade
Dwarf yaupon holly	Ilex vomitoria cv.Schellings	5' O.C.	1 gal	part shade/part sun
Saw palmetto	Serenoa repens	5' O.C.	3 gal	full sun to full shade
American beautyberry	Callicarpa americana	5' O.C.	1 gal	part shade/part sun
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities should be focused on the major system components, especially landscaping and the overflow structures. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the overflow structures consists of regular inspection for clogging.

Irrigation for the bioretention cells might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than non-native plants.

Table A.5-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.5-3. Maintenance Tasks for Bioretention

Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on the location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining 1"-3" uniform mulch layer.
Mulch removal	1 time/2-3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the bioretention BMP. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.5-4 and Figure A.5-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.5-4. SUSTAIN Model Load Reductions for Site P1-1031

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	767,269	532,367	234,902	31%
Total Nitrogen (lbs)	112	44	68	61%

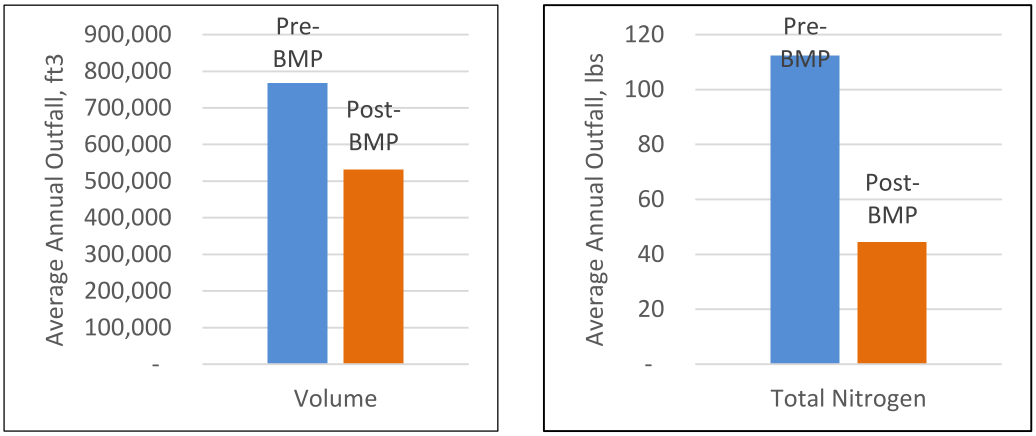


Figure A.5-3. SUSTAIN Model Load Reductions for Site P1-1031

Cost Opinion

The estimated costs of implementing bioretention at the Cape Coral Sports Center are presented in Table A.5-5. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $1,666.00.

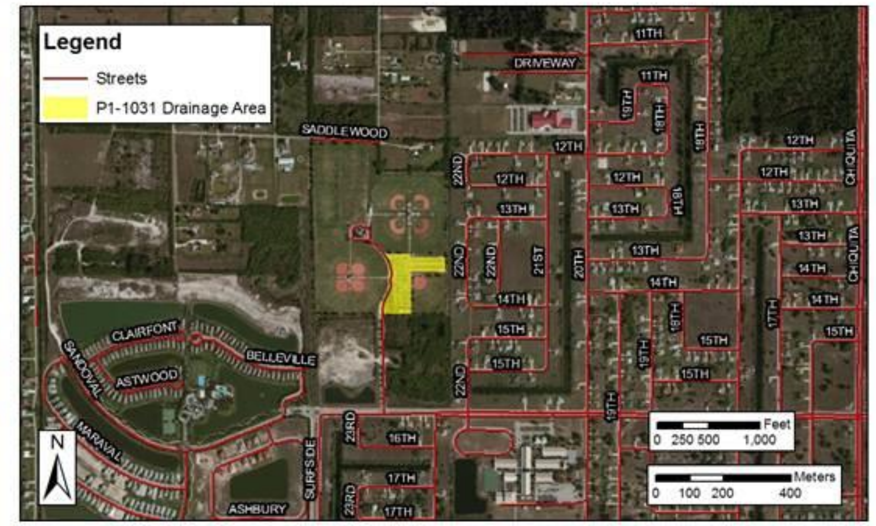
Table A.5-5. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	475	LF	$2.50	$1,187.50
2	Silt Fence	475	LF	$3.00	$1,425.00
	Site Preparation				
3	Excavation and Removal	1250	CY	$8.52	$10,650.00
	Bioretention				$0.00
4	4 inch Perforated Pipe	1350	LF	$2.00	$2,700.00
5	Gravel Subbase - 6 inches	8400	SF	$0.55	$4,620.00
6	Fine Grading	8400	SF	$0.72	$6,048.00
7	Soil Amendments	150	CY	$13.00	$1,950.00
	Landscaping				
8	Vegetation	6300	SF	$4.00	$25,200.00
Construction Subtotal					**$53,780.50**
9	Utility Adj (5% of subtotal)				$2,689.03
10	Planning (10% of subtotal)				$5,378.05
11	Design (30% of subtotal)				$16,134.15
12	Mobilization (10% of subtotal)				$5,378.05
13	Contingency (20% of subtotal)				$10,756.10
Construction Total					**$94,115.88**
14	20-Year O&M	8400	SF	$2.28	$19,152.00
Total Cost					**$113,267.88**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.5.

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1031



Project Narrative

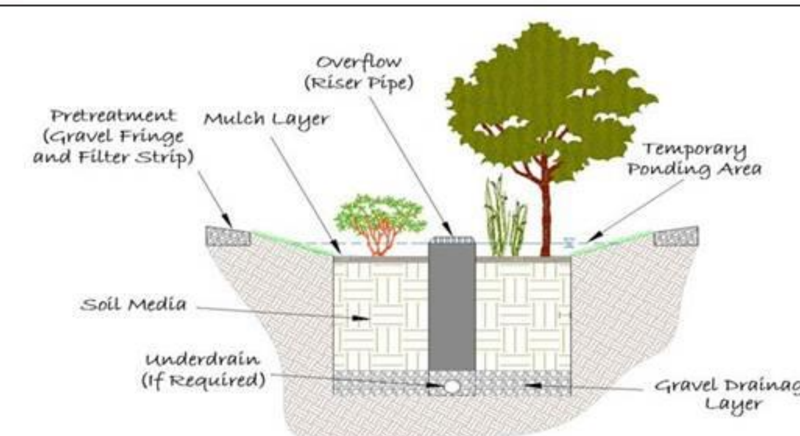
This project proposes replacing the existing detention basin with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for Cape Coral, and in this case presents an excellent opportunity as a retrofit of an existing detention basin.

Site Location

Site ID	P1-1031	**Latitude**	26° 37' 37.56" N
Project Name	TBD	**Longitude**	82° 01' 15.03" W
Date of Field Visit	12/01/2014	**Street Address**	Sports Boulevard
Field Visit Personnel	EB, DS	**Landowner**	City of Cape Coral

Project site, north of parking lot facing northeast

Project site, Project site, north of parking lot facing northeast with proposed Bioretention



Example Bioretention Retrofit Cross Section

TETRA TECH

EXHIBIT A.5

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1031


Project site, with cross section layer view


Project site, alternate vegetation arrangement

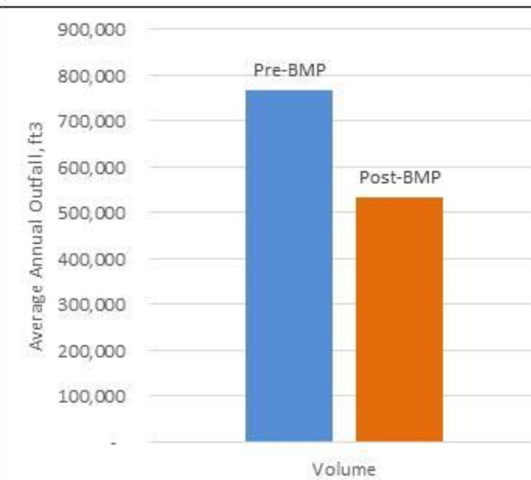
Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

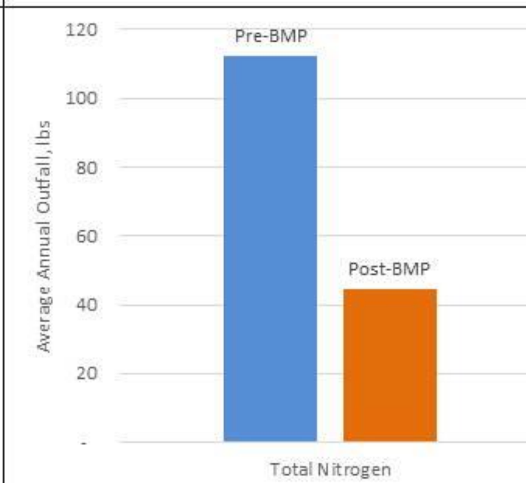

Project site, aerial view of drainage area


Project site, aerial view of drainage area with proposed Bioretention

Planning	$5,378
Design	$16,134
Contingency	$10,756
Mobilization	$5,378
Construction	$53,780
20-year O&M	$19,152
Total Cost	**$113,268**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	767,269	532,367	234,902	31%
Total Nitrogen, (lbs)	112	44	68	61%





TETRA TECH

EXHIBIT
A.5

6. P1-1008: Four Seasons Park - Bioretention Retrofit

Project Location and Description

The project is located in the City owned Four Seasons Park at Sunnybrook Avenue between Bimini Basin, Beach Court, and Tarpon Court. There are several businesses and facilities along Sunnybrook Avenue and Beach Court including TIB Bank, Ice Sssscreamin!, SunTrust Bank, and residential housing. Figure A.6-1 shows the project location and contributing drainage area.

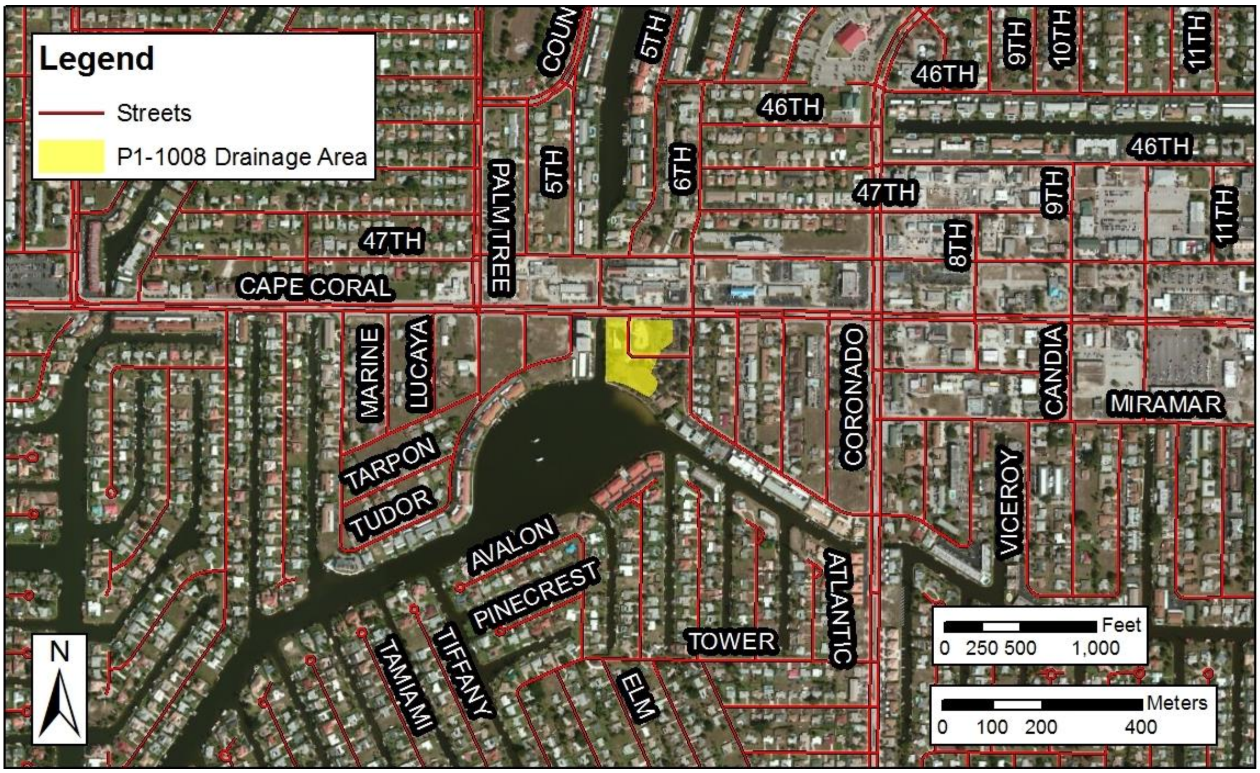


Figure A.6-1. Project Location for Site P1-1008

This project proposes replacing the existing grass and landscaped vegetation that is over the existing stormwater pipe network within Four Freedoms Park with bioretention. Stormwater runoff from both the park and surrounding areas contributing to the pipe network will be treated. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. Therefore, this type of device is a good option for the park.

The total contributing drainage area is approximately 3.87 acres and encompasses the west side of the park and much of the developed areas north to Cape Coral Parkway. The park is graded to direct flow towards existing pipe network and outfalls into the Bimini Basin as shown in Figure A.6-2.

Figure A.6-2. Existing Drainage Patterns for Site P1-1008

BMP Sizing

As a general guideline, bioretention should occupy at least 5 to 7 percent of the drainage area to treat the first inch of runoff (first flush). Other guidance, such as that provided by EPA, recommends that bioretention treat the 85th to 95th percentile storm event which for the City was calculated to be about 1.27 to 2.19 inches respectively. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. For this project, the original conceptual configuration for bioretention, and the one that would have the least impact on the existing park layout, represents about 1 percent of the drainage area. In that configuration, the project is generally too small to treat the first inch of runoff. Therefore, the BMP configuration in this concept plan was increased in size to represent about 5 percent of the contributing drainage for adequate storage, stormwater conveyance, and water quality treatment. For this concept, we initially tried to minimize impacts to the overall layout and function of the park, however, a larger BMP is required based on the drainage area.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert the existing grass/landscaped area over the storm drain into bioretention cells. The location utilizes the existing drainage patterns and is configured "on-line" to minimize excavation, grading, demolition, and piping. The BMP configuration and typical cross-section details are provided in Exhibit A.4.

Overflow Structure

During on-line flow all runoff from the drainage area flows into the bioretention system. Flows that exceed the design capacity exit the bioretention area via an overflow structure or weir. The following considerations should be included in the final overflow design:

- The overflow device must convey runoff to the canal.
- Common overflow systems within bioretention consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically between 6 to 12 inches above the surface of the filter bed.
- The overflow device should be scaled to the application.
- At least 3 to 6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.

Soil Media

The bioretention cells should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges are shown in Table A.6-1.

Table A.6-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	• Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) • Cation Exchange Capacity (CEC) greater than 10 • Soil pH between 5.5 and 7.0 • Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioretention system fully drains within 72 hours or less.

Plant Selection

For the bioretention cells to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
- It is recommended that a minimum of three tree, three shrub, and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.6-2.

Table A.6-2. Plant Species for Bioretention

Common name	Scientific Name	Spacing	Container Size	Light
Dahoon holly	Ilex cassine	10' O.C.	3 gal	full sun to partial shade
Cabbage palm	Sabal palmetto	10' O.C.	3 gal	full sun to partial shade
Wax myrtle	Myrica cerifera	5' O.C.	1 gal	full sun to partial shade
Shyny lyonia	lyonia lucida	5' O.C.	1 gal	full sun to partial shade
Dwarf yaupon holly	Ilex vomitoria cv.Schellings	5' O.C.	1 gal	part shade/part sun
Saw palmetto	Serenoa repens	5' O.C.	3 gal	full sun to full shade
American beautyberry	Callicarpa americana	5' O.C.	1 gal	part shade/part sun
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities should be focused on the major system components, especially landscaping and the overflow structures. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the overflow structures consists of regular inspection for clogging.

Irrigation for the bioretention cells might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than non-native plants.

Table A.6-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.6-3. Maintenance Tasks for Bioretention

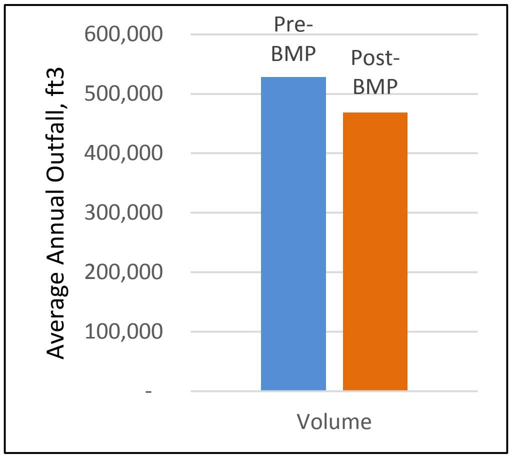
Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on the location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining 1"-3" uniform mulch layer.
Mulch removal	1 time/2-3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the bioretention BMP. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.6-4 and Figure A.6-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.6-4. SUSTAIN Model Load Reductions for Site P1-1008

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	528,167	317,447	210,720	40%
Total Nitrogen (lbs)	101	33	68	67%



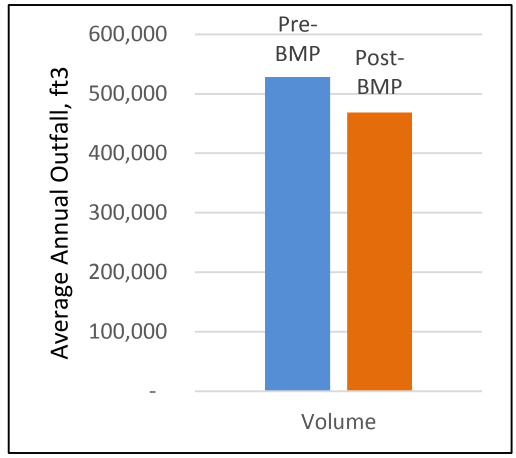


Figure A.6-3. SUSTAIN Model Load Reductions for Site P1-1008

Cost Opinion

The estimated costs of implementing bioretention at the City owned Four Seasons Park are presented in Table A.6-5. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $1,842.00.

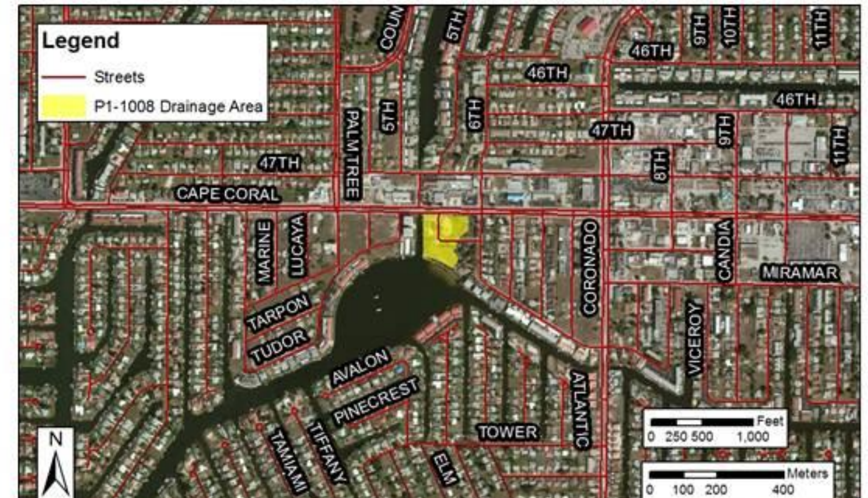
Table A.6-5. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	500	LF	$2.50	$1,250.00
2	Silt Fence	500	LF	$3.00	$1,500.00
	Site Preparation				
3	Excavation and Removal	950	CY	$8.52	$8,094.00
	Bioretention				$0.00
4	4 inch Perforated Pipe	2100	LF	$2.00	$4,200.00
5	Gravel Subbase - 6 inches	8400	SF	$0.55	$4,620.00
6	Fine Grading	8400	SF	$0.72	$6,048.00
7	Soil Amendments	100	CY	$13.00	$1,300.00
	Landscaping				
8	Vegetation	8400	SF	$4.00	$33,600.00
Construction Subtotal					**$60,612.00**
9	Utility Adj (5% of subtotal)				$3,030.60
10	Planning (10% of subtotal)				$6,061.20
11	Design (30% of subtotal)				$18,183.60
12	Mobilization (10% of subtotal)				$6,061.20
13	Contingency (20% of subtotal)				$12,122.40
Construction Total					**$106,071.00**
14	20-Year O&M	8400	SF	$2.28	$19,152.00
Total Cost					**$125,223.00**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.6.

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1008



Project Narrative

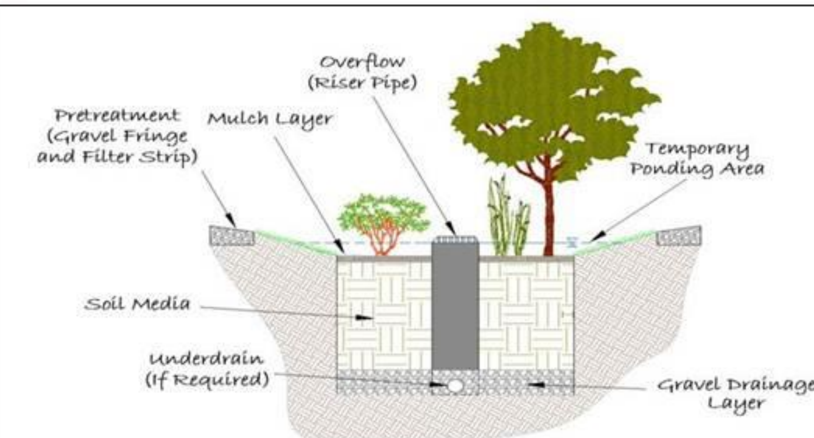
This project proposes replacing the existing grass and landscaped vegetation that is over the existing stormwater pipe network within Four Freedoms Park with bioretention. Stormwater runoff from both the park and surrounding areas contributing to the pipe network will be treated. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. Therefore, this type of device is a good option for the park.

Site Location

Site ID	P1-1008	**Latitude**	26° 33' 42.14" N
Project Name	TBD	**Longitude**	81° 57' 46.67" W
Date of Field Visit	12/08/2014	**Street Address**	Sunntbrook Court
Field Visit Personnel	EB, DS	**Landowner**	City of Cape Coral

Project site, corner of Sunntbrook Court and Beach Court

Project site, corner of Sunntbrook Court and Beach Court with proposed Bioretention



Example Bioretention Retrofit Cross Section

TETRA TECH

EXHIBIT A.6

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1008

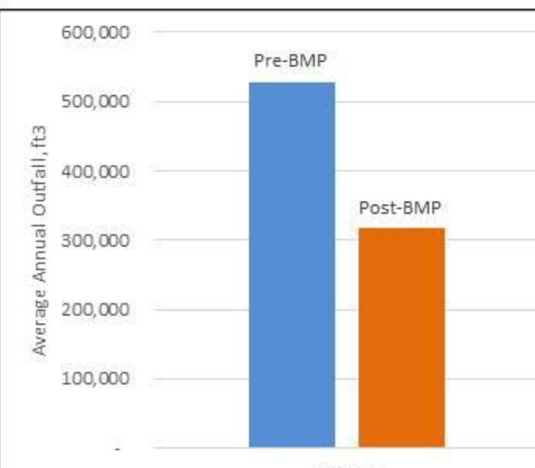
Project site, NW park entrance facing south

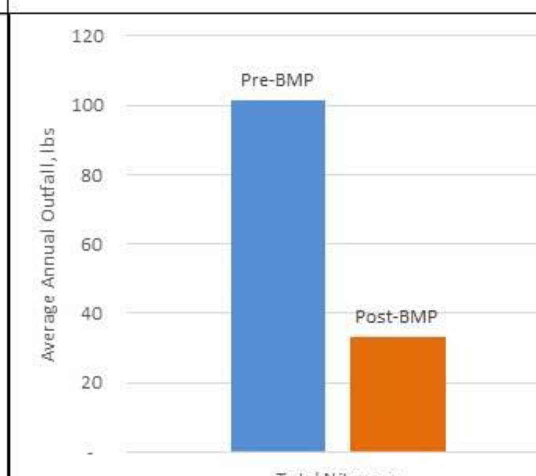
Project site, NW park entrance facing south with proposed Bioretention

Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

Planning	$6,061
Design	$18,184
Contingency	$12,122
Mobilization	$6,061
Construction	$60,612
20-year O&M	$19,152
Total Cost	**$125,223**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	528,167	317,447	210,720	40%
Total Nitrogen, (lbs)	101	33	68	67%





TETRA TECH

EXHIBIT
A.6

7. P1-1044: Veterans Foundation - Parking Lot Retrofit

Project Location and Description

The project is located in the City owned parking for the Veterans Foundation. There are several businesses and facilities surrounding the parking lot including Rib City, Bank of America, and a Chiropractic office building. Figure A.7-1 shows the project location.

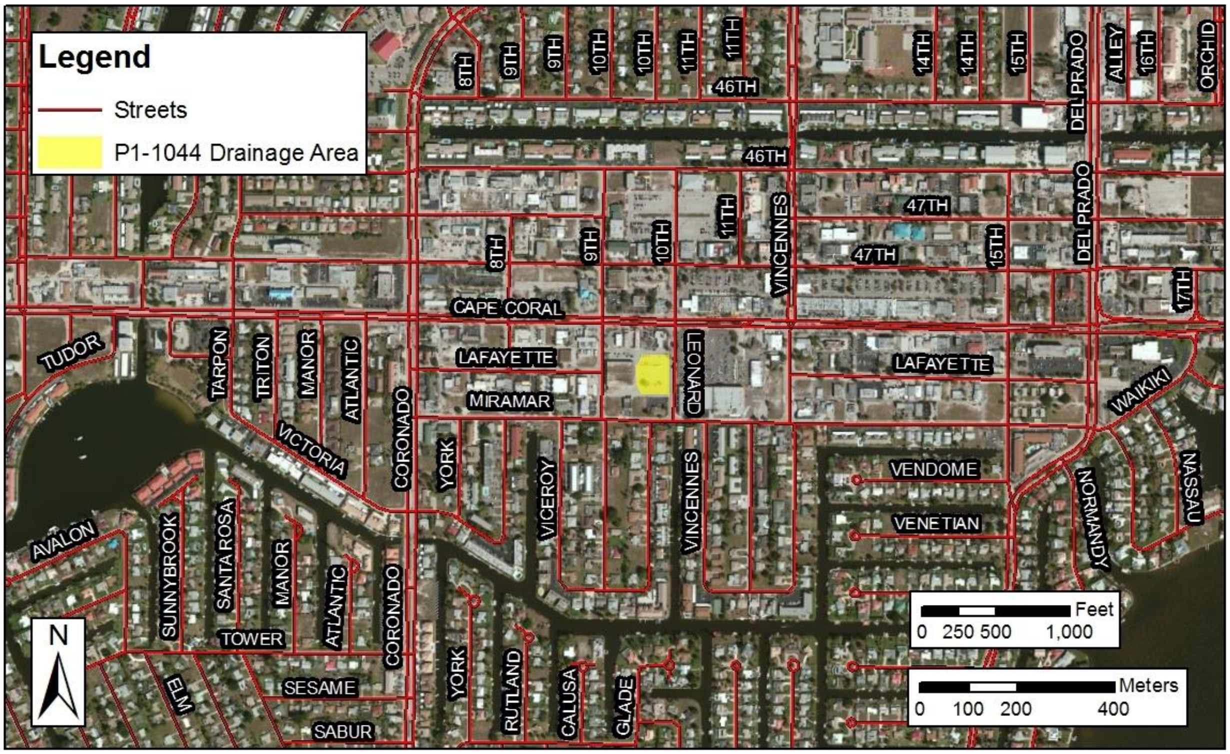


Figure A.7-1. Project location for site P1-1044

This project proposes adjusting the existing parking patterns and retrofitting with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for the City, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here.

The total contributing drainage area is approximately 1.4 acres and encompasses the entire parking lot. The parking lots are graded to direct flow towards the storm drain grate inlets and then into stormwater pipes as shown in Figure A.7-2.

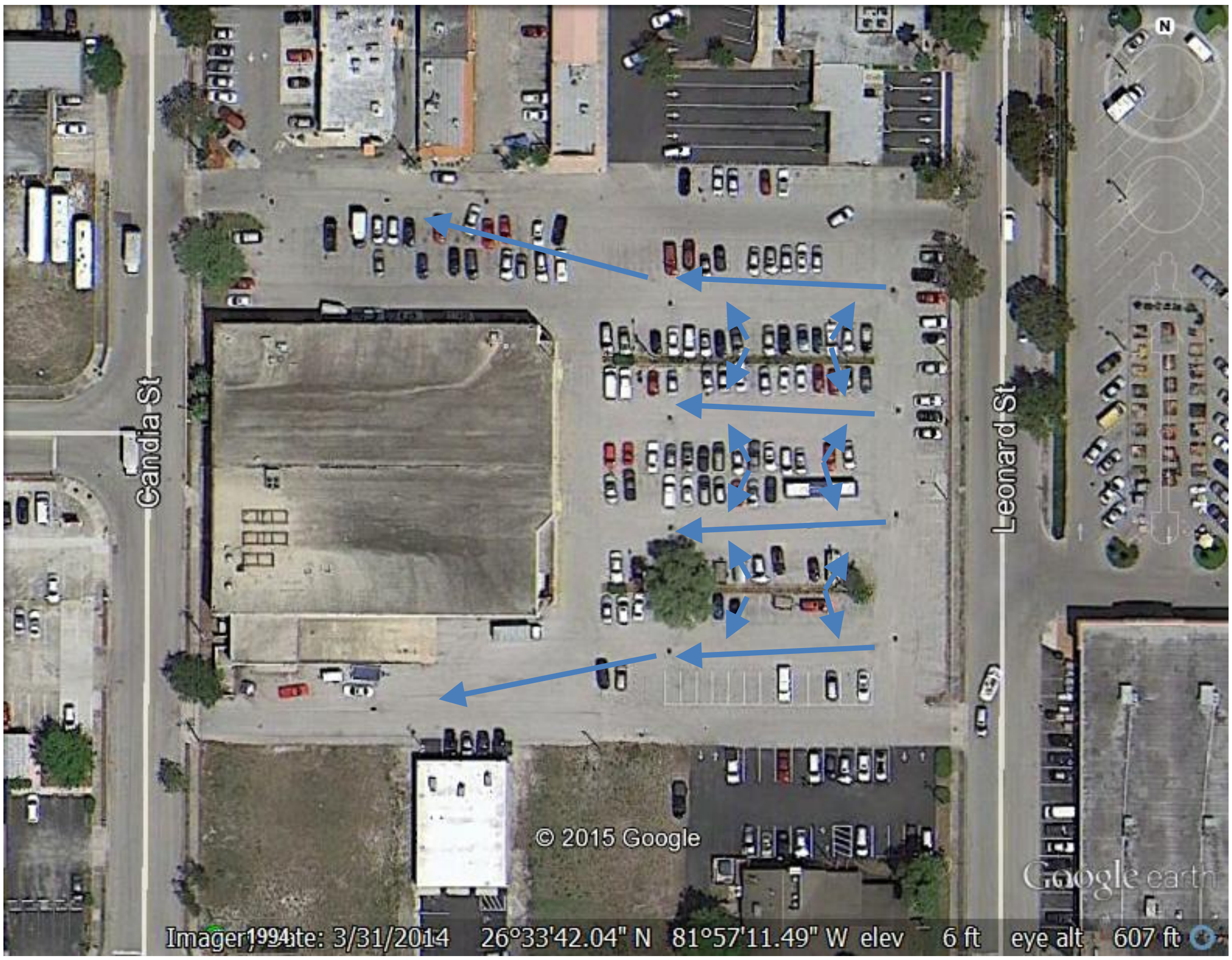


Figure A.7-2. Existing Drainage Patterns for Site P1-1044

BMP Sizing

As a general guideline, bioretention should occupy at least 5 to 7 percent of the drainage area to treat the first inch of runoff (first flush). Other guidance, such as that provided by EPA, recommends that bioretention treat the 85^{th} to 95^{th} percentile storm event which for the City was calculated to be about 1.27 to 2.19 inches respectively. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. For this project, the area available for bioretention represents about 14.3 percent of the drainage area. Thus, the suggested retrofit configuration of the area available for bioretention should be considered adequate for cost effective treatment.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert the existing catch basins into bioretention areas in order to capture concentrated sheet flow from the parking lot for treatment. The location utilizes the existing drainage patterns and is configured “on-line” to minimize excavation, grading, demolition, and piping. The BMP configuration and typical cross-section details are provided in Exhibit A.6.

Overflow Structure

During on-line flow all runoff from the drainage area flows into the bioretention system. Flows that exceed the design capacity exit the bioretention area via an overflow structure or weir. The following considerations should be included in the final overflow design:

- The overflow device must convey runoff to the storm sewer.
- Common overflow systems within bioretention consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically between 6 to 12 inches above the surface of the filter bed.
- The overflow device should be scaled to the application.
- At least 3 to 6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.

Soil Media

The bioretention cells should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.7-1.

Table A.7-1. Soil Media Specifications

<table>
<tr><th>Material</th><th>Specification</th><th>Notes</th></tr>
<tr><td>Filter Media Composition</td><td>85-88% sand
8-12% soil fines
3-5% organic matter in form of leaf compost</td><td>The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.</td></tr>
<tr><td>Filter Media Testing</td><td colspan="2">Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.)
Cation Exchange Capacity (CEC) greater than 10
Soil pH between 5.5 and 7.0
Mix on-site or procure from an approved media vendor</td></tr>
<tr><td>Top Soil</td><td colspan="2">4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter</td></tr>
<tr><td>Permeability</td><td colspan="2">Infiltration should be 0.5 in/hr or greater</td></tr>
</table>

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioretention system fully drains within 72 hours or less.

Plant Selection

For the bioretention cells to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
- It is recommended that a minimum of three tree, three shrub, and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.7-2.

Table A.7-2. Plant Species for Bioretention

Common name	Scientific Name	Spacing	Container Size	Light
Dahoon holly	Ilex cassine	10' O.C.	3 gal	full sun to partial shade
Cabbage palm	Sabal palmetto	10' O.C.	3 gal	full sun to partial shade
Wax myrtle	Myrica cerifera	5' O.C.	1 gal	full sun to partial shade
Shyny lyonia	lyonia lucida	5' O.C.	1 gal	full sun to partial shade
Dwarf yaupon holly	Ilex vomitoria cv.Schellings	5' O.C.	1 gal	part shade/part sun
Saw palmetto	Serenoa repens	5' O.C.	3 gal	full sun to full shade
American beautyberry	Callicarpa americana	5' O.C.	1 gal	part shade/part sun
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities should be focused on the major system components, especially landscaping and the overflow structures. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the overflow structures consists of regular inspection for clogging.

Irrigation for the bioretention cells might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than non-native plants.

Table A.7-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.7-3. Maintenance Tasks for Bioretention

Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on the location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining 1"-3" uniform mulch layer.
Mulch removal	1 time/2-3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the bioretention BMP. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.7-4 and Figure A.7-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.7-4. SUSTAIN Model Load Reductions for Site P1-1044

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	272,552	108,809	163,742	60%
Total Nitrogen (lbs)	84	13	71	84%

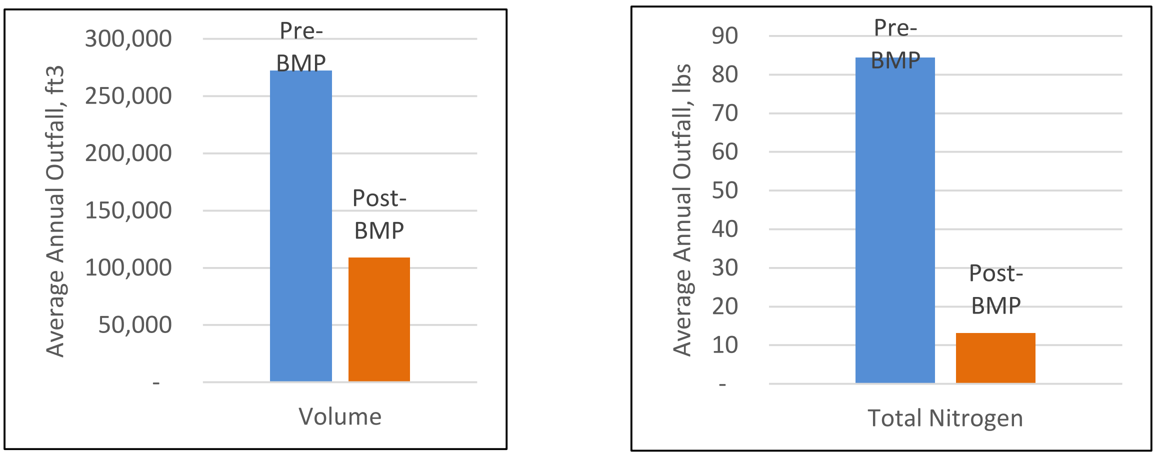


Figure A.7-3. SUSTAIN Model Load Reductions for Site P1-1044

Cost Opinion

The estimated costs of implementing bioretention at the City owned parking lot are presented in Table A.7-5. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $1,941.00.

Table A.7-5. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	1400	LF	$2.50	$3,500.00
2	Silt Fence	1400	LF	$3.00	$4,200.00
	Site Preparation				
3	Excavation and Removal	1200	CY	$8.52	$10,224.00
	Bioretention				
4	4 inch Perforated Pipe	1120	LF	$2.00	$2,240.00
5	Gravel Subbase - 6 inches	8400	SF	$0.55	$4,620.00
6	Fine Grading	8400	SF	$0.72	$6,048.00
7	Soil Amendments	160	CY	$13.00	$2,080.00
	Landscaping				
8	Vegetation	8400	SF	$4.00	$33,600.00
Construction Subtotal					**$66,512.00**
9	Utility Adj (20% of subtotal)				$13,302.40
10	Planning (10% of subtotal)				$6,651.20
11	Design (40% of subtotal)				$26,604.80
12	Mobilization (10% of subtotal)				$6,651.20
13	Contingency (20% of subtotal)				$13,302.40
14	Demolition (20% of subtotal)				$13,302.40
15	Parking (20% of subtotal)				$13,302.40
Construction Total					**$133,024.00**
16	20-Year O&M	2100	SF	$2.28	$4,788.00
Total Cost					**$137,812.00**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.7.

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1044

Project Narrative

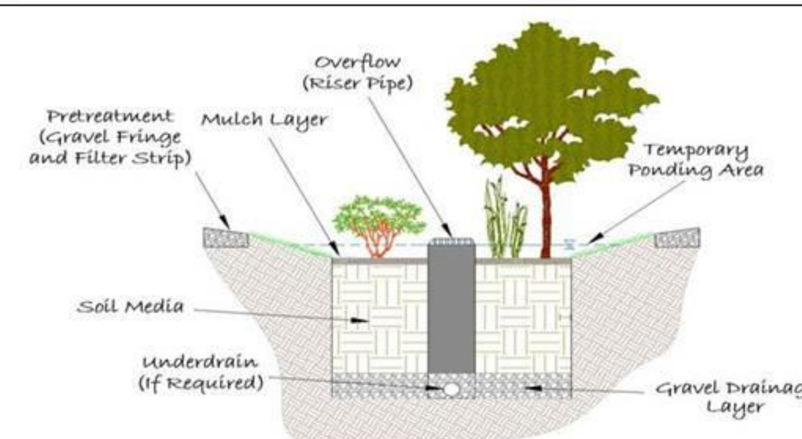
This project proposes adjusting the existing parking patterns and retrofitting with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for Cape Coral, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here.

Site Location

Site ID	P1-1044	Latitude	26° 33' 42.04" N
Project Name	TBD	Longitude	81° 57' 11.49" W
Date of Field Visit	12/08/2014	Street Address	Leonard Street
Field Visit Personnel	EB, DS	Landowner	City of Cape Coral

Project site, south portion of parking lot facing east

Project site, south portion of parking lot facing east with proposed Bioretention



Example Bioretention Retrofit Cross Section

TETRA TECH

EXHIBIT A.7

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1044

Project site, view from Leonard Street

Project site, view from Leonard Street with proposed Bioretention cell (1 of 4)

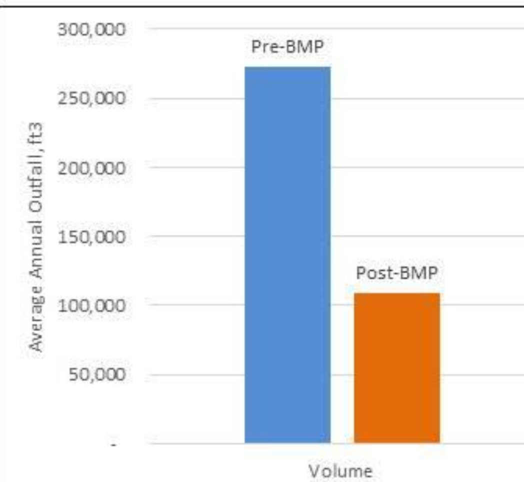
Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

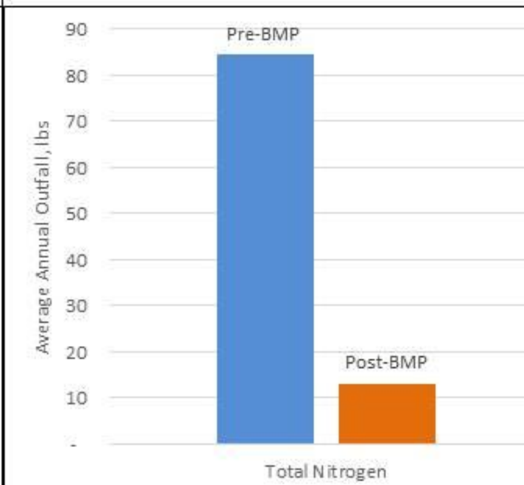
Project site, north portion of parking lot facing west

Project site, north portion of parking lot facing west with proposed Bioretention

Planning	$6,651
Design	$26,605
Contingency	$13,302
Mobilization	$6,651
Construction	$66,512
20-year O&M	$4,788
Total Cost	**$137,812**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	272,552	108,809	163,742	60%
Total Nitrogen, (lbs)	84	13	71	84%





TETRA TECH

EXHIBIT A.7

8. Ditch: NE Pine Island Lane – Ditch Retrofit

Project Location and Description

The project is located in a City owned stormwater conveyance ditch between Pine Island Road and NE Pine Island Lane. A commercial building, with parking, is currently constructed adjacent to NE Pine Island Lane. Figure A.8-1 shows the project location and contributing drainage area.

Figure A.8-1. Project Location

This project proposes retrofitting the existing stormwater conveyance ditch that runs behind the developed commercial building with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping.

The total contributing drainage area is approximately 5.3 acres and encompasses the commercial building roof runoff, as well as the parking lot for the building. The commercial property is currently graded to direct flow towards a perimeter swale which then directs flow into stormwater pipes at the property frontage as shown in the Figure A.8-2. The perimeter swales would have to be re-graded to direct runoff to the back of the commercial property to direct flow into the stormwater conveyance ditch.

Figure A.8-2. Existing Drainage Patterns for Site

BMP Sizing

As a general guideline, bioretention should occupy at least 5 to 7 percent of the drainage area to treat the first inch of runoff (first flush). Other guidance, such as that provided by EPA, recommends that bioretention treat the 85^{th} to 95^{th} percentile storm event which for the City was calculated to be about 1.27 to 2.19 inches respectively. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. For this project, the area available for bioretention represents about 8.9 percent of the drainage area. Thus, the suggested retrofit configuration of the area available for bioretention should be considered adequate for cost effective treatment.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert the existing ditch into bioretention in order to capture concentrated runoff from the commercial building and parking lot. The location can be adapted to be configured "on-line" to minimize excavation, grading, demolition, and piping. The BMP configuration and typical cross-section details are provided in Exhibit A.9.

Overflow Structure

During on-line flow all runoff from the drainage area flows into the bioretention system. Flows that exceed the design capacity exit the bioretention area via an overflow structure or weir. The following considerations should be included in the final overflow design:

- The overflow device must convey runoff to the storm sewer.
- Common overflow systems within bioretention consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically between 6 to 12 inches above the surface of the filter bed.
- The overflow device should be scaled to the application.
- At least 3 to 6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.

Soil Media

The bioretention cells should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.8-1.

Table A.8-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) Cation Exchange Capacity (CEC) greater than 10. Soil pH between 5.5 and 7.0 Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioretention system fully drains within 72 hours or less.

Plant Selection

For the bioretention cells to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
- It is recommended that a minimum of three tree, three shrub, and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.8-2.

Table A.8-2. Plant Species for Bioretention

Common name	Scientific Name	Spacing	Container Size	Light
Dahoon holly	Ilex cassine	10' O.C.	3 gal	full sun to partial shade
Cabbage palm	Sabal palmetto	10' O.C.	3 gal	full sun to partial shade
Wax myrtle	Myrica cerifera	5' O.C.	1 gal	full sun to partial shade
Shyny lyonia	lyonia lucida	5' O.C.	1 gal	full sun to partial shade
Dwarf yaupon holly	Ilex vomitoria cv.Schellings	5' O.C.	1 gal	part shade/part sun
Saw palmetto	Serenoa repens	5' O.C.	3 gal	full sun to full shade
American beautyberry	Callicarpa americana	5' O.C.	1 gal	part shade/part sun
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities should be focused on the major system components, especially landscaping and the overflow structures. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the overflow structures consists of regular inspection for clogging.

Irrigation for the bioretention cells might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than non-native plants.

Table A.8-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.8-3. Maintenance Tasks for Bioretention

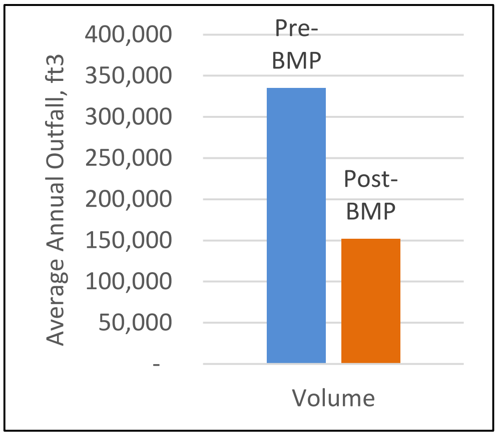
Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on the location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining 1"-3" uniform mulch layer.
Mulch removal	1 time/2-3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the bioretention BMP. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.8-4 and Figure A.8-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.8-4. SUSTAIN Model Load Reductions

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	335,466	152,213	183,153	55%
Total Nitrogen (lbs)	73	15	58	79%



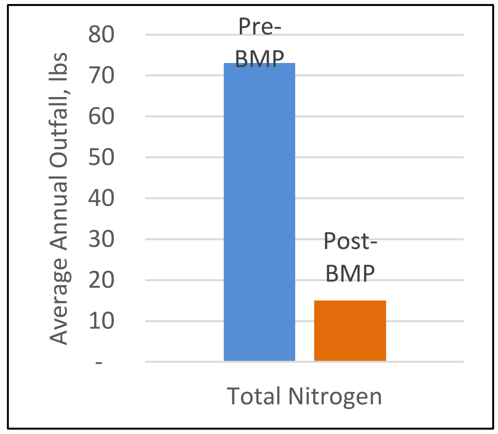


Figure A.8-3. SUSTAIN Model Load Reductions

Cost Opinion

The estimated costs of implementing bioretention at the City owned stormwater conveyance ditch are presented inTable A.8-5. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $2,320.00

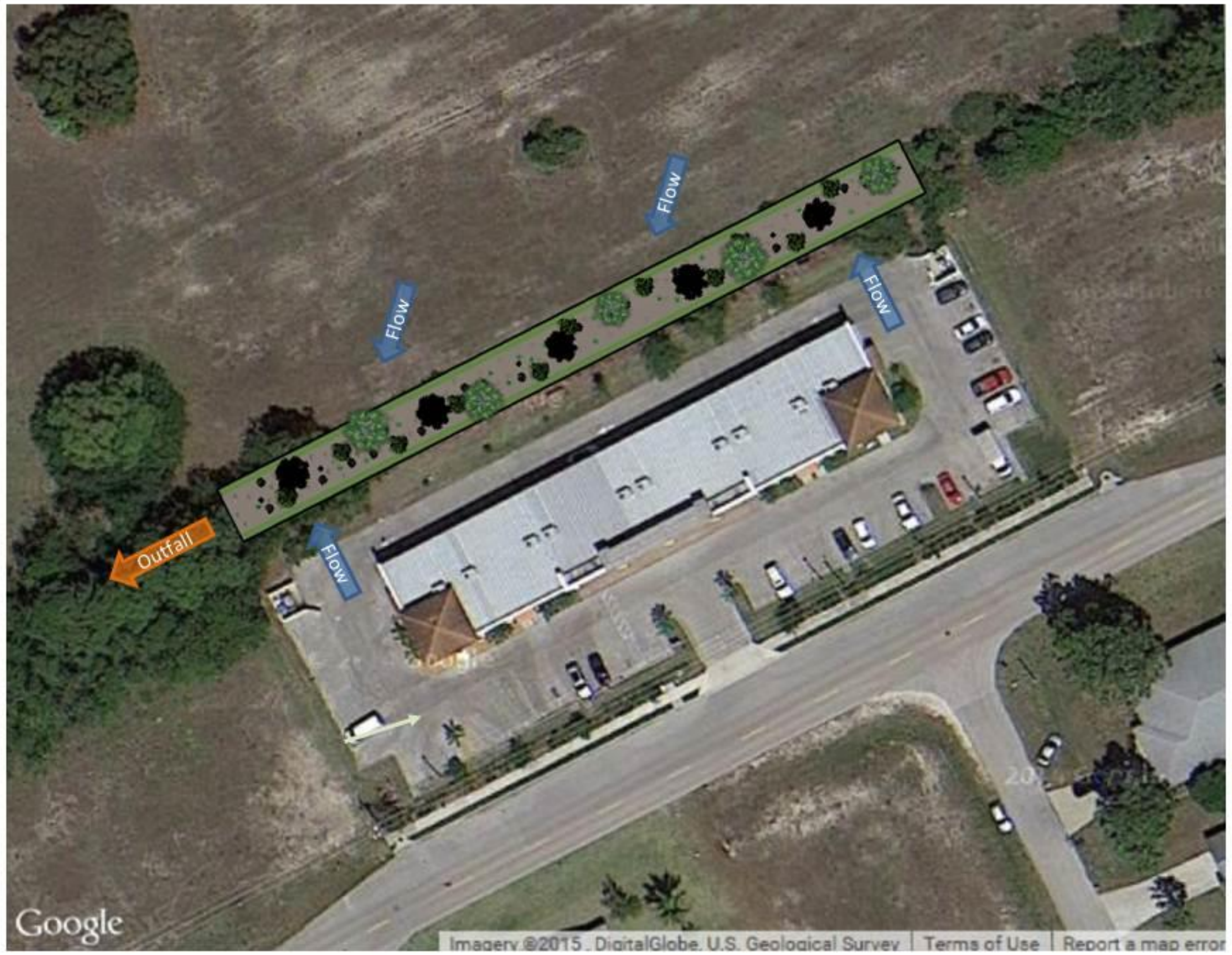
Table A.8-5. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	750	LF	$2.50	$1,875.00
2	Silt Fence	750	LF	$3.00	$2,250.00
	Site Preparation				
3	Excavation and Removal	975	CY	$8.52	$8,307.00
	Bioretention				
4	4 inch Perforated Pipe	2100	LF	$2.00	$4,200.00
5	Gravel Subbase - 6 inches	8750	SF	$0.55	$4,812.50
6	Fine Grading	8750	SF	$0.72	$6,300.00
7	Soil Amendments	70	CY	$13.00	$910.00
	Landscaping				
8	Vegetation	8750	SF	$4.00	$35,000.00
Construction Subtotal					**$63,654.50**
9	Utility Adj (5% of subtotal)				$3,182.73
10	Planning (10% of subtotal)				$6,365.45
11	Design (30% of subtotal)				$19,096.35
12	Mobilization (10% of subtotal)				$6,365.45
13	Contingency (25% of subtotal)				$15,913.63
Construction Total					**$114,578.10**
14	20-Year O&M	8750	SF	$2.28	$19,950.00
Total Cost					**$134,528.10**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.8.

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: Ditch



Project Narrative

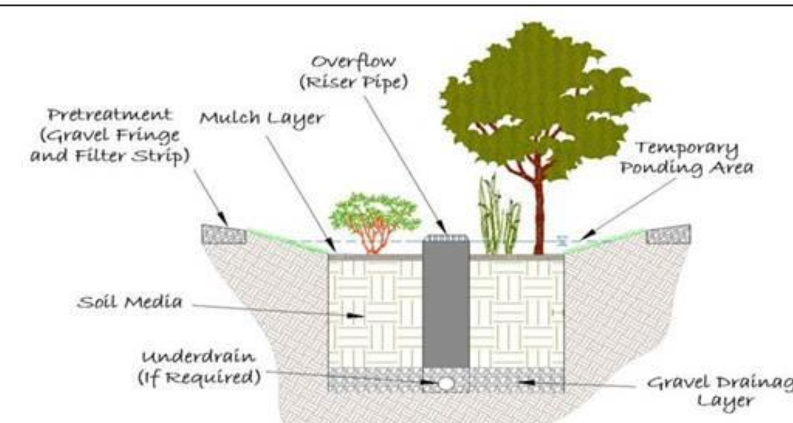
This project proposes retrofitting the existing stormwater conveyance ditch that runs behind the developed commercial building with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping.

Site Location

Site ID	Ditch	**Latitude**	26° 39' 29.03" N
Project Name	TBD	**Longitude**	81° 57' 31.78" W
Date of Field Visit	12/08/2014	**Street Address**	NE Pine Island Lane
Field Visit Personnel	EB, DS	**Landowner**	City of Cape Coral

Project site, facing northeast

Project site, facing northeast with proposed Bioretention



Example Bioretention Retrofit Cross Section

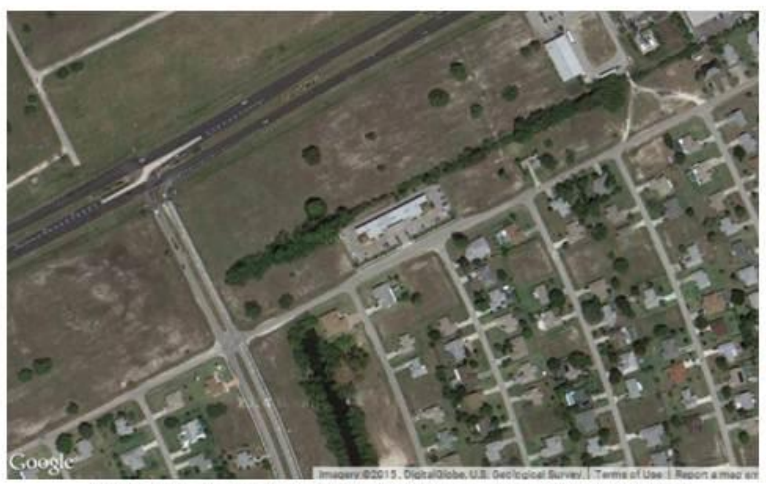
TETRA TECH

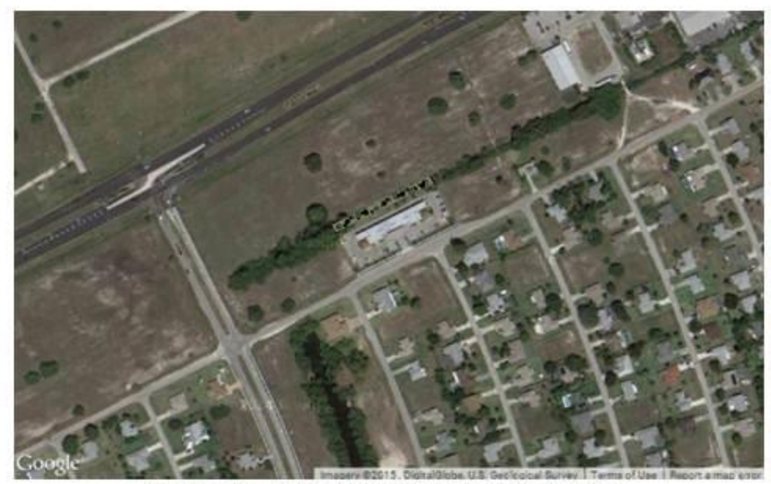
EXHIBIT A.8


Project site, view from Pine Island Lane NE


Project site, view from Pine Island Lane NE with proposed Bioretention behind building

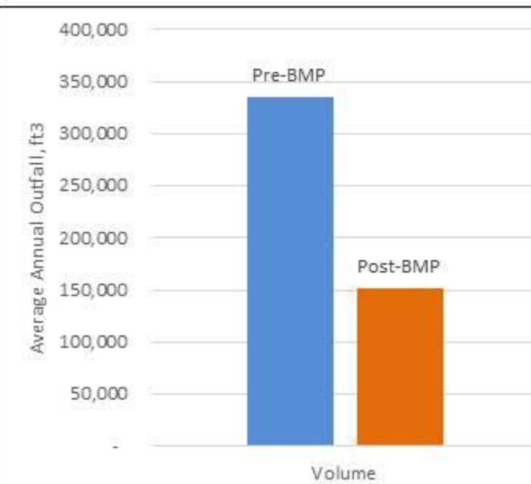
Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

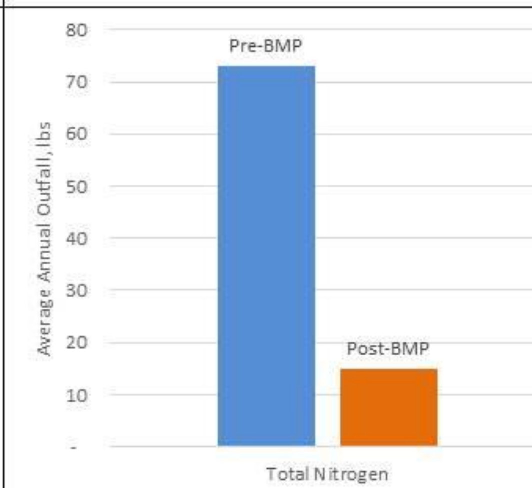

Project site, aerial view of Pine Island Lane NE and nearby canal


Project site, aerial view with proposed Bioretention

Planning	$6,365
Design	$19,096
Contingency	$15,913
Mobilization	$6,365
Construction	$63,654
20-year O&M	$19,950
Total Cost	**$134,528**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	335,466	152,313	183,153	55%
Total Nitrogen, (lbs)	73	15	58	79%





CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: Ditch

TETRA TECH

EXHIBIT
A.8

9. P1-1035: Academy Blvd Boat Ramp - Stormwater Wetland

Project Location and Description

The project is located in the vacant City owned parcel adjacent to Academy Blvd and between Nicholas Pkwy E and SE 13th St. The parcel is zoned as park/recreation and the area surrounding the parcel is a mix of commercial, industrial, and residential. Figure A.9-1 shows the project location.

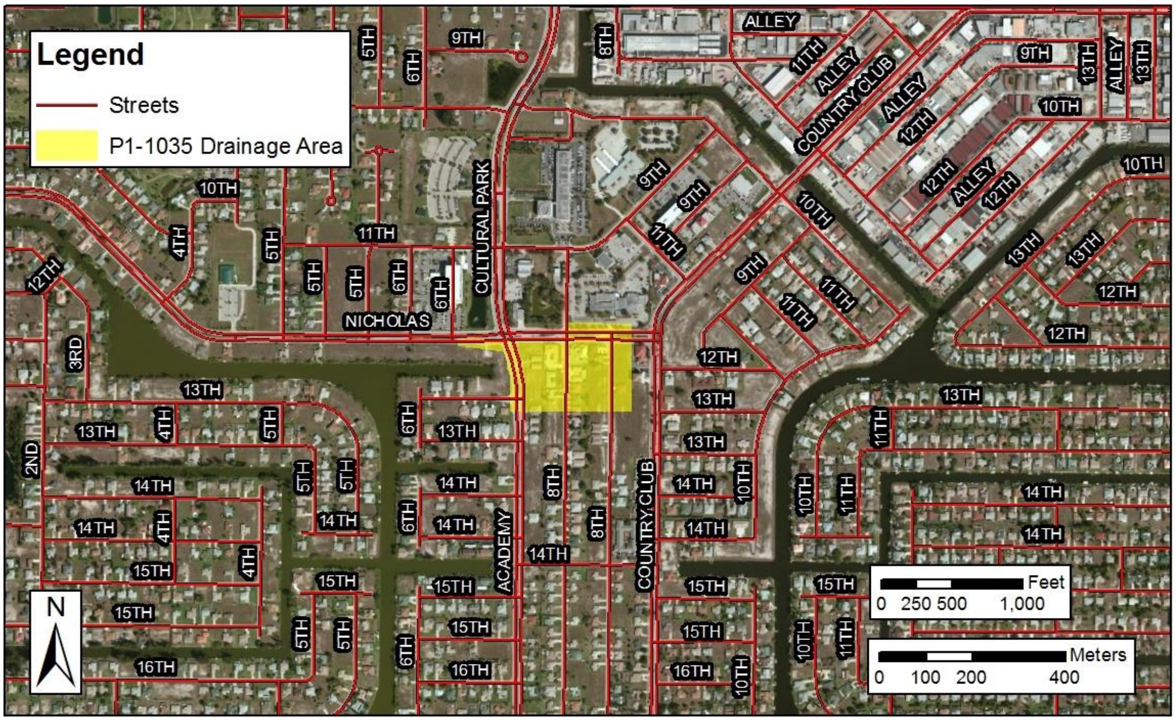


Figure A.9-1. Project Location for Site P1-1035

This project proposes the creation of a stormwater wetland in the vacant City owned parcel. Stormwater wetlands are an excellent option for water quality treatment because they are able to absorb excess nutrients. The project proposes that water from an existing storm drain be directed into the constructed wetland. The water will then flow through a series of shallow and deep wetland areas for treatment before discharging into the canal system at two locations via control structures. In order to ensure that the wetland maintains a permanent pool, a secondary clay soil liner, or geomembrane, will likely be required to limit infiltration. A geotechnical investigation and laboratory analysis should be performed prior to the final design to determine existing soil conditions, hydraulic conductivity, and whether the aforementioned "liner" will be needed.

The total contributing drainage area is approximately 12.1 acres. Existing flow paths are show inFigure A.9-2.

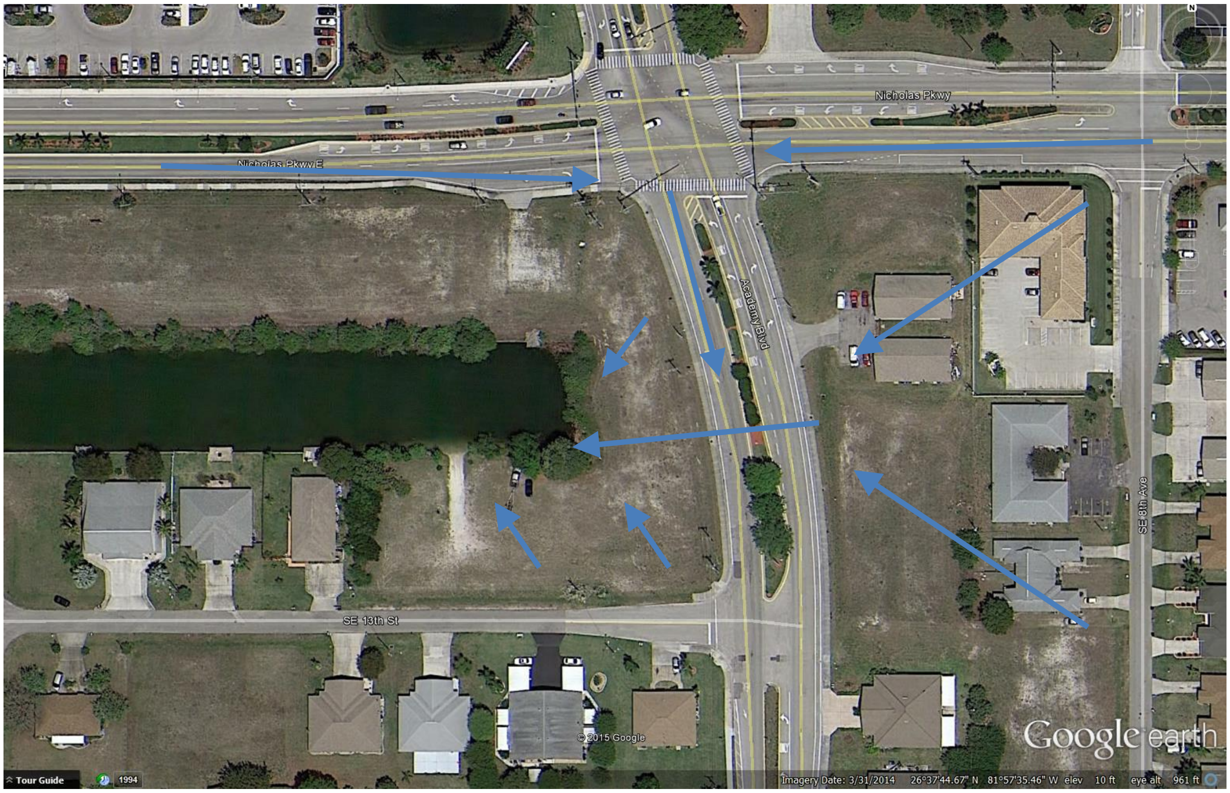


Figure A.9-2. Existing Drainage Patterns for Site P1-1035

BMP Sizing

For the purpose of this conceptual plan, it was assumed that the marsh can be designed to hold about 2.5 feet of water on average below the control elevation. The drainage area to the wetland was calculated to be just over 12 acres and the wetland size as shown in this concept is just under ½ acre. There is additional space available within the parcel if the hydrologic conditions used for final design indicate a larger wetland is required. Similarly, the size may be adjusted if groundwater or other features such as utilities restrict depth.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert the existing grass area into a stormwater wetland in order to capture stormwater from the existing stormwater drain for treatment. There are two outlet structures that will control the water surface elevation and release treated water to the canal system. The BMP configuration and typical cross-section details are provided in Exhibit A.8.

Plant Selection

For the stormwater wetland to function properly as water quality treatment and enhance the landscape, vegetation selection is crucial. It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the planting zone, recommended spacing, minimum container size, and planting elevations is provided in Table A.9-1.

Table A.9-1. Plant Species for Stormwater Wetland

Planting Zone	Common name	Scientific Name	Spacing	Container Size	Planting Elevation
A	Sand Cordgrass	*Spartina bakeri*	3' O.C.	4" pot	0' to -0.5'
	Soft Rush	*Juncus effuses*	3' O.C.	4" pot	0' to -0.5'
	Blue Maidencane	*Ampicarpum sp.*	3' O.C.	4" pot	0' to -0.5'
	St. John's Wort	*Hypericum fasiculatum*	5' O.C.	1 gal	0' to -0.5'
B	Golden Canna	*Canna flaccida*	3' O.C.	4" pot	-0.5' to -1.0'
	Maidencane	*Panicum hemitomon*	3' O.C.	4" pot	-0.5' to -1.0'
	Pickerelweed	*Pontederia cordata*	3' O.C.	4" pot	-0.5' to -1.0'
	Sawgrass	*Cladium jamaicensis*	3' O.C.	4" pot	-0.5' to -1.0'
	Buttonbush	*Cephalanthus occidentalis*	5' O.C.	1 gal	-0.5' to -1.0'
C	Arrowhead	*Sagittaria lancifolia*	3' O.C.	4" pot	-1.0' to -1.5'
	Maidencane	*Panicum hemitomon*	3' O.C.	4" pot	-1.0' to -1.5'
D	Alligator Flag	*Thalia geniculate*	3' O.C.	4" pot	-1.5' to -2.0'
	Soft-stem Bulrush	*Scirpus validus*	3' O.C.	4" pot	-1.5' to -2.0'
	Waterlilly	*Nymphaea odorata*	5' O.C.	B.R.	-1.5' to -2.0'

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities for the stormwater wetland should be focused on the major system components, especially landscaping and conveyance infrastructure. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the conveyance infrastructure consists of regular inspections.

Table A.9-2 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.9-2. Maintenance Tasks for Stormwater Wetland

Task	Frequency	Maintenance Notes
Remove exotic and nuisance vegetation	1 time/year	Manual control (hand weeding) is the preferred method of removal.
Infrastructure inspection	4 times/year	Check conveyance infrastructure to ensure that everything is functioning as designed.
Miscellaneous upkeep	4 times/year	Tasks include trash collection, plant health, spot weeding, and removing any sediment buildup.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the constructed stormwater wetland. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.9-3 and Figure A.9-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via pollutant uptake from the vegetation within the BMP and through microbial activity.

Table A.9-3. SUSTAIN Model Load Reductions for Site P1-1035

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	1,196,071	835,699	360,373	30%
Total Nitrogen (lbs)	185	129	56	30%

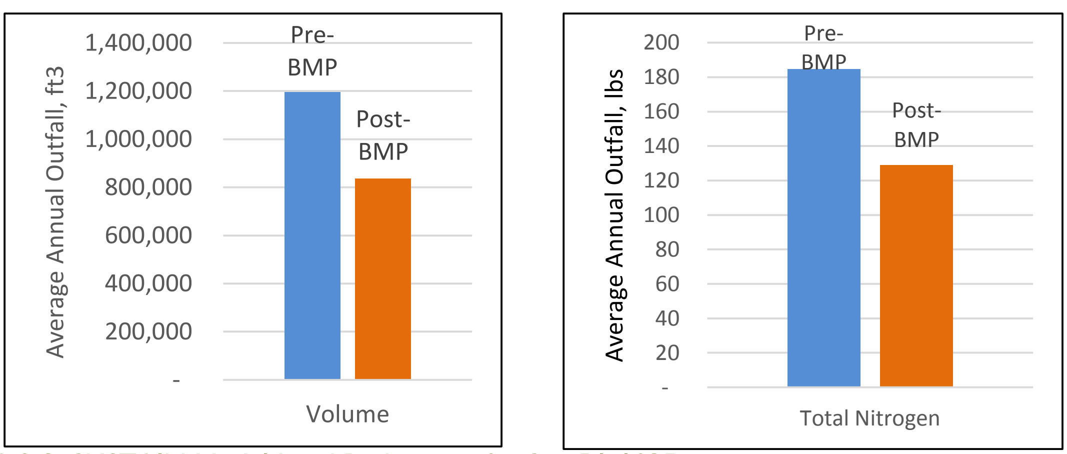


Figure A.9-3. SUSTAIN Model Load Reductions for Site P1-1035

Cost Opinion

The estimated costs of implementing the stormwater wetland at the vacant City owned parcel are presented in Table A.9-4. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $2,587.00 per pound removed.

Table A.9-4. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	600	LF	$2.50	$1,500.00
2	Silt Fence	600	LF	$3.00	$1,800.00
	Site Preparation				
3	Excavation and Removal	2431	CY	$8.52	$20,708.33
	Filter Marsh				
	12" Clay Liner	694	CY	$25.00	$17,361.11
4	6" Top Soil	694	CY	$13.00	$9,027.78
5	Fine Grading	18,750	SF	$0.72	$13,500.00
6	Outlet Control Structures	2	Each	$5,000.00	$10,000.00
7	Landscaping				
8	Vegetation	6188	SF	$2.50	$15,468.75
Construction Subtotal					**$89,365.97**
9	Planning (5% of subtotal)				$4,468.30
10	Design (35% of subtotal)				$31,278.09
11	Mobilization (5% of subtotal)				$4,468.30
12	Contingency (15% of subtotal)				$13,404.90
Construction Total					**$142,985.56**
13	20-Year O&M	18,750	SF	$0.10	$1,875.00
Total Cost					**$144,860.56**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.9.

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CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1035

Project Narrative

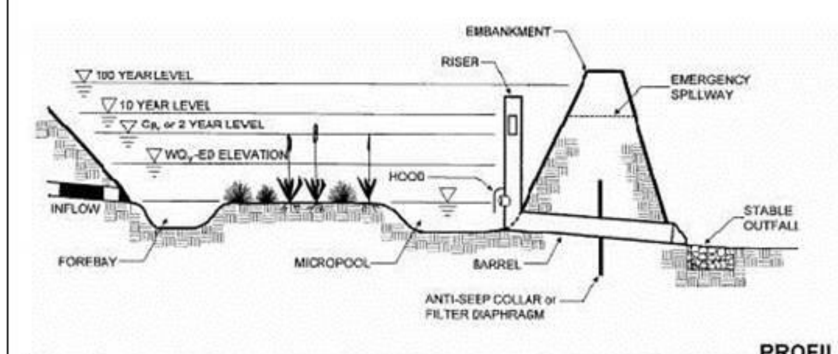
This project proposes the creation of a stormwater wetland in the vacant City owned parcel. Stormwater wetlands are an excellent option for water quality treatment because they are able to absorb excess nutrients. The project proposes that water from an existing storm drain be directed into the constructed wetland. The water will then flow through a series of shallow and deep wetland areas for treatment before discharging into the canal system at two locations via control structures. In order to ensure that the wetland maintains a permanent pool, a secondary clay soil liner or geomembrane will likely be required to limit infiltration. A geotechnical investigation and laboratory analysis should be performed prior to the final design to determine existing soil conditions, hydraulic conductivity, and whether the aforementioned "liner" will be needed.

Site Location

Site ID	P1-1035	**Latitude**	26° 37' 45.42" N
Project Name	TBD	**Longitude**	81° 57' 36.17" W
Date of Field Visit	12/02/2014	**Street Address**	Academy Boulevard
Field Visit Personnel	EB, DS	**Landowner**	City of Cape Coral

Project site, from Academy Boulevard facing East

Project site, from Academy Boulevard facing East with proposed wet pond



Example Constructed Wetland Cross Section (US EPA)

TETRA TECH

EXHIBIT A.9

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1035

Project site, corner of Academy Blvd and 13th Street SE

Project site, corner of Academy Blvd and 13th Street SE with proposed wet pond

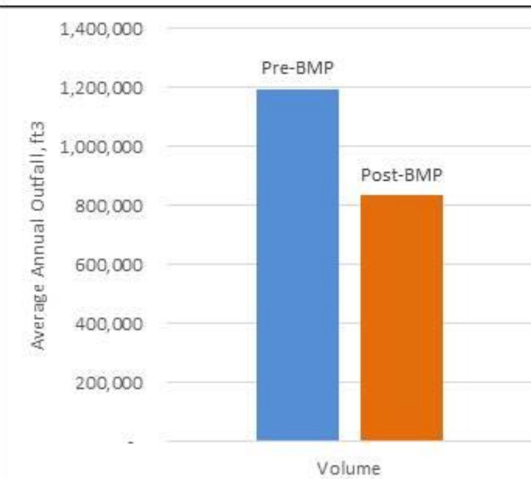
Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

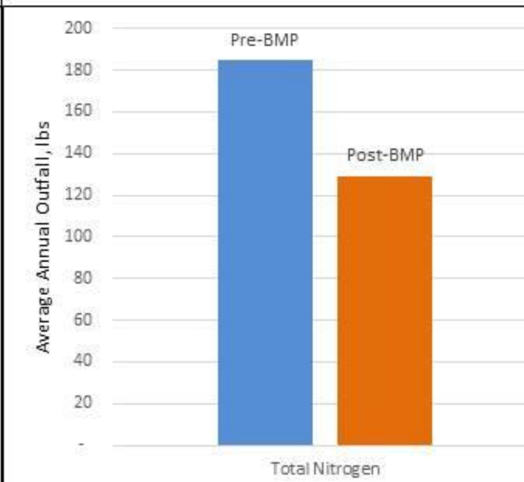
Project site, from Acadamy Blvd facing southeast

Project site, from Acadamy Blvd facing southeastwith proposed wet pond

Planning	$4,468
Design	$31,278
Contingency	$13,405
Mobilization	$4,468
Construction	$89,366
20-year O&M	$1,875
Total Cost	**$144,861**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	1,196,071	835,699	360,373	30%
Total Nitrogen, (lbs)	185	129	56	30%





TETRA TECH

EXHIBIT
A.9

10. Vacant City Parcel: Saltwater Filter Marsh

Per Acre Assessment for Vacant City Owned Parcels

Site selection for filter marsh opportunities involved the use of City provided GIS shapefiles to identify vacant, City-owned land parcels larger than five acres in size. To use these parcels for water quality treatment, they need to be reasonably close to canals, and also have inlet/outlet combinations that do not create a feedback loop of treated canal water. The final candidates for treatment sites are presented in Figure A.10-1. Table A.10-1 provides a summary of estimated per acre total nitrogen (TN) load reductions and estimated cost per pound per acre removed for filter marshes that are constructed on City owned parcels.

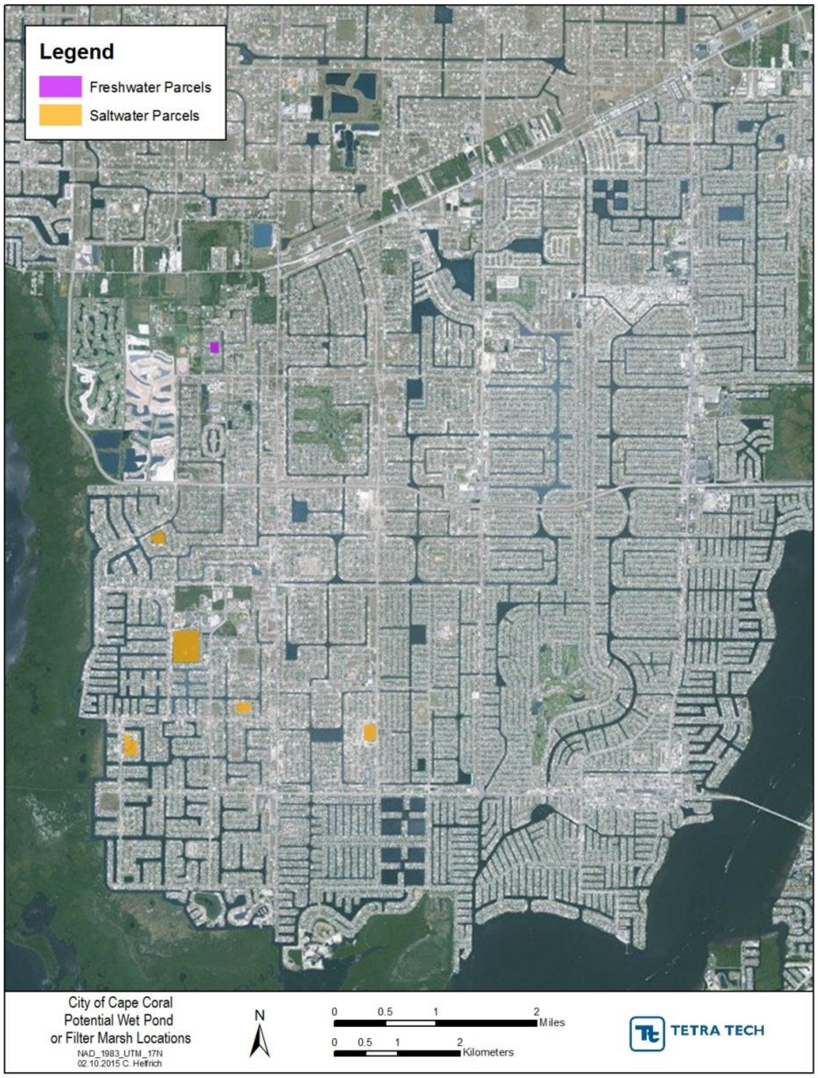


Figure A.10-1. Vacant City Owned Parcels Larger the 5 Acres

Table A.10-1. Wet Pond and Filter Marsh Results – Per Acre

Project	Potential Average TN Removal (lb/acre/year)	Average Estimated Cost ($/lb/acre/year)
Freshwater Filter Marsh	27.39	$ 4,747
Saltwater Filter Marsh	35.13	$ 3,701

The concept plan outlined below was the only more specific/detailed concept plan created for filter marshes because of the higher cost versus other water quality management opportunities identified in the City and because there is some uncertainty regarding the effectiveness of a constructed saltwater marsh. If constructed, the AIM/Tetra Tech team encourages the City to monitor the inflow and outflow results to determine if filter marshes at the other identified sites should be constructed.

Project Location and Description

The project is located in the vacant City owned parcel that is bordered by SW 41st Street, SW 18th Avenue, SW 42nd Street, and SW 19th Avenue. The parcel is zoned as park/recreation and the area surrounding the parcel is residential. Figure A.10-2 shows the project location.

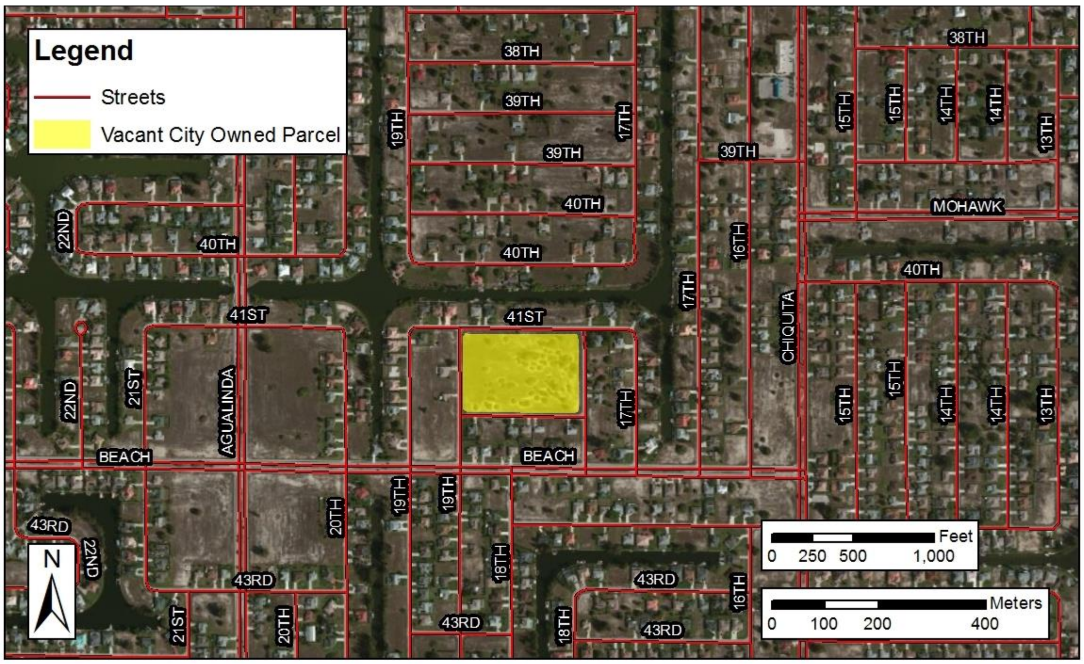


Figure A.10-2. Project Location

This project proposes the creation of a saltwater filter marsh and park in the vacant City owned parcel. The combination of park and marsh will provide an amenity to the residents of the City while also providing water quality treatment. Filter marshes are an excellent option for water quality treatment because they are able to absorb excess nutrients. The project proposes that water from the canal north of the parcel be diverted into the marsh via pump. The water will then flow through a series of shallow and deep wetland areas for treatment before discharging into the separate canal system southwest of the parcel via a control structure and/or pumps and pipes.

BMP Sizing

For the purpose of this conceptual plan, it was assumed that about 75 percent of the parcel could be allocated for filter marsh and the remaining area could be allocated for trails and other park amenities. The parcel is 7.87 acres. Therefore, 5.9 acres were designated filter marsh and the remaining 1.97 acres were designated park. It was assumed that the marsh can be designed to hold about 2.5 feet of water on average below the control elevation and the residence time would be 5 days. To calculate flow, the assumed pool volume was divided by the residence time.

BMP Conceptual Layout

The suggested BMP configuration is intended to treat canal water from north of the parcel and discharged to a completely separate canal system southwest of the parcel. However, the process could be designed to work in reverse if site conditions and/or measured TN concentrations indicate this would be more advantageous. The BMP configuration and typical cross-section details are provided in Exhibit A.10

Plant Selection

For the saltwater filter marsh to function properly as water quality treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will depend on the salinity of the canal water. It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. Typical vegetation in saline tidal marshes include Smooth Cordgrass, Short Smooth Cordgrass, Spike Grass, and Saltmeadow Rush. If the water is brackish, there will be a greater variety of plant options available.

Operations and Maintenance

Maintenance activities for the saltwater filter marsh should be focused on the major system components, especially landscaping, pumps, and conveyance infrastructure. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility’s life span and reduce the need for extensive maintenance. The primary maintenance requirement for the pumps and conveyance infrastructure consists of regular inspections.

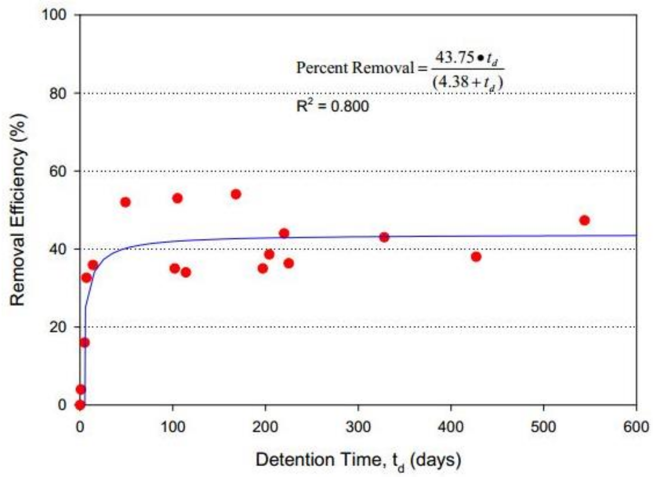
Table A.10-2 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.10-2. Maintenance Tasks for Filter Marsh

Task	Frequency	Maintenance Notes
Remove exotic and nuisance vegetation	1 time/year	Manual control (hand weeding) is the preferred method of removal.
Pump and infrastructure inspection	4 times/year	Check pumps and conveyance infrastructure to ensure that everything is functioning as designed.
Miscellaneous upkeep	4 times/year	Tasks include trash collection, plant health, spot weeding, and removing any sediment buildup.

Total Nitrogen Load Impacts

TN removal for the filter marsh is based on a variety of factors. The most dominant factor is residence time, which is the amount of time water spends in the marsh before exiting. An ideal scenario allows enough time for unwanted constituents to either settle out of the water column, or be removed through natural chemical and biological processes. According to the DEP's Stormwater Quality Applicant's Handbook, TN removal efficiency can be determined by the following relationship and equation:



Variable t_d represents detention time (residence time). Hydraulic detention time is governed by flow rate, which would be controlled by the pump system(s). The following equation relates flow rate to detention time:

$$t_d = (\phi)*(AxD)/(Q)$$

Variable ϕ, A, D, *and* Q represents the marsh's soil porosity, area, depth, and flow rate respectively.

For the filter marsh, a residence time of 5 days was used to calculate the flow and removal efficiency that might be expected. Table A.10-3 and Figure A.10-3highlight the total annual load reduction for TN. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.10-3. Load Reductions for the Filter Marsh

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Total Nitrogen (lbs)	692	415	277	40%

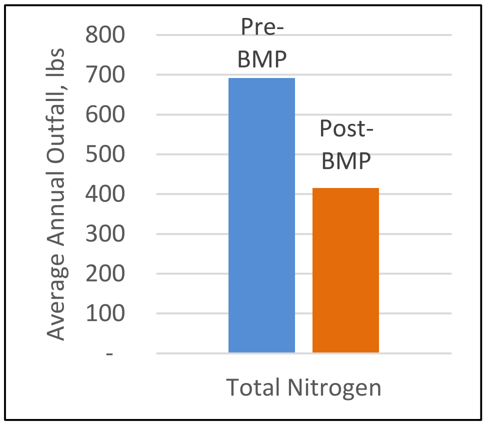


Figure A.10-3. Load Reductions for the Filter Marsh

Cost Opinion

The estimated costs of implementing the filter marsh at the vacant City owned parcel are presented in Table A.10-4. These costs do not include paths or other park amenities. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $3,691.25 per pound removed.

Table A.10-4. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	2250	LF	$2.50	$5,625.00
2	Silt Fence	2250	LF	$3.00	$6,750.00
	Site Preparation				
3	Excavation and Removal	28593	CY	$8.52	$243,616.21
	Filter Marsh				
4	6" Top Soil	4766	CY	$13.00	$61,952.48
5	Fine Grading	257341	SF	$0.72	$185,285.57
6	Pumps and Infrastructure	2	Each	$10,000.00	$20,000.00
7	Landscaping				
8	Vegetation	128671	SF	$1.50	$193,005.80
Construction Subtotal					**$716,235.06**
9	Planning (2% of subtotal)				$14,324.70
10	Design (20% of subtotal)				$143,247.01
11	Mobilization (2% of subtotal)				$14,324.70
12	Contingency (15% of subtotal)				$107,435.26
Construction Total					**$995,566.73**
13	20-Year O&M	257341.1	SF	$0.10	$25,734.11
Total Cost					**$1,021,300.84**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.10.

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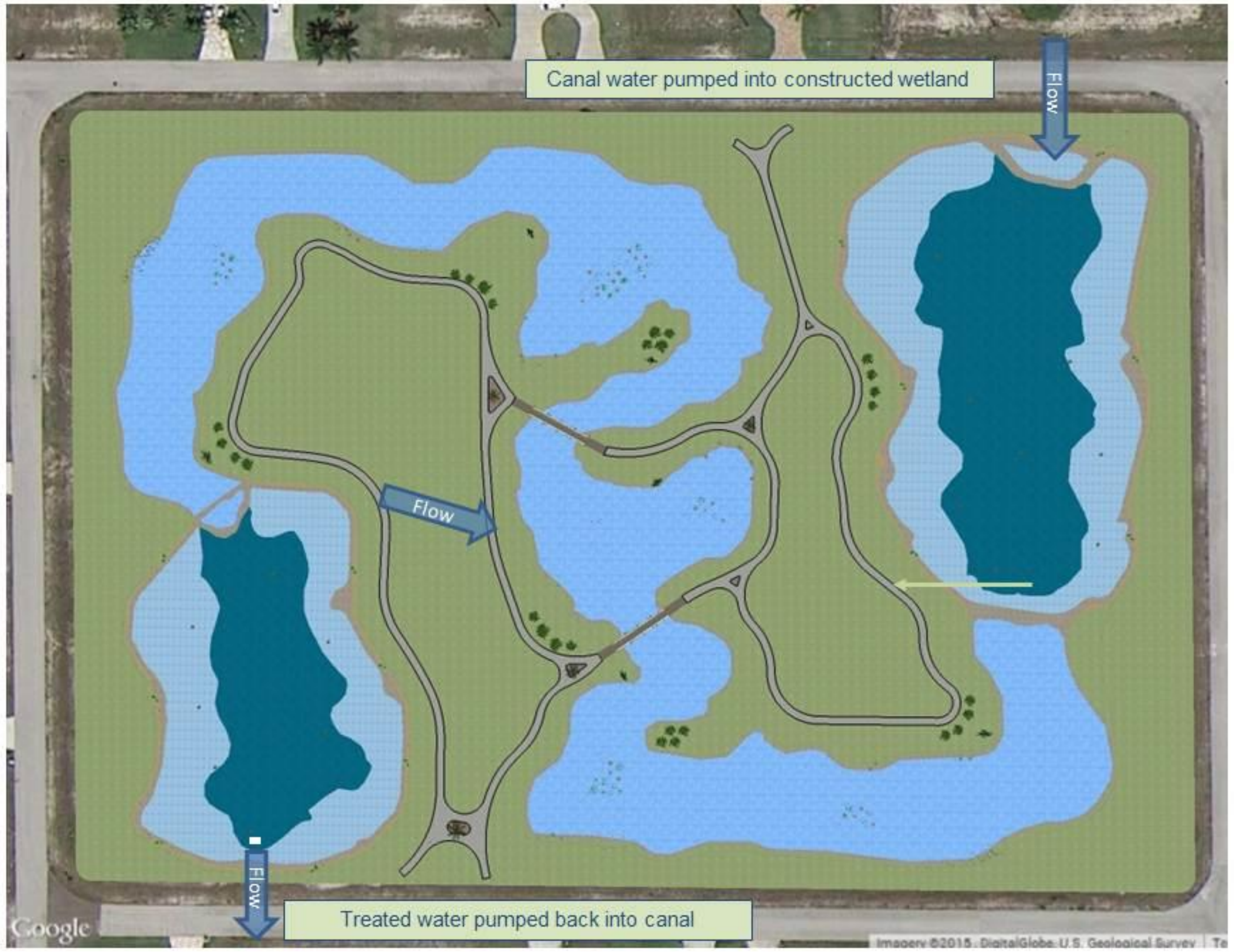
CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: CITY-WIDE FILTER MARSH/DETENTION POND TREATMENT



Project Narrative

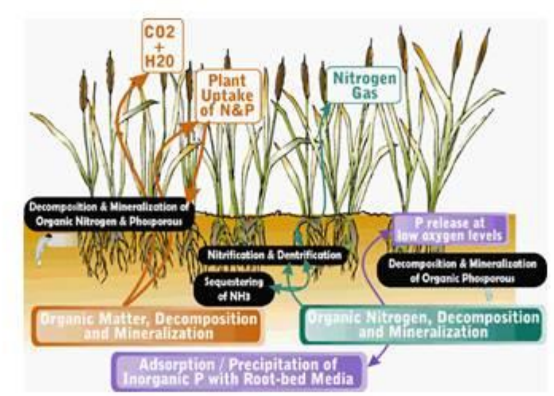
This project proposes the creation of a saltwater filter marsh and park in the vacant City owned parcel. The combination of park and marsh will provide an amenity to the residents of the City while also providing water quality treatment. Filter marshes are an excellent option for water quality treatment because they are able to absorb excess nutrients. The project proposes that water from the canal north of the parcel be diverted into the marsh via pump. The water will then flow through a series of shallow and deep wetland areas for treatment before discharging into the separate canal system southwest of the parcel via a control structure and/or pumps and pipes.

Site Location

Site ID	Vacant Parcel	**Latitude**	26° 34' 29.12" N
Project Name	Filter Marsh	**Longitude**	82° 00' 42.79" W
Date of Field Visit	N/A	**Street Address**	SW 41st Street
Field Visit Personnel	N/A	**Landowner**	City of Cape Coral

Example Project site, corner of 42st St SW and 18th Ave facing SW

Example Project site, corner of 42st St SW and 18th Ave facing SW with proposed wetland and filter marsh

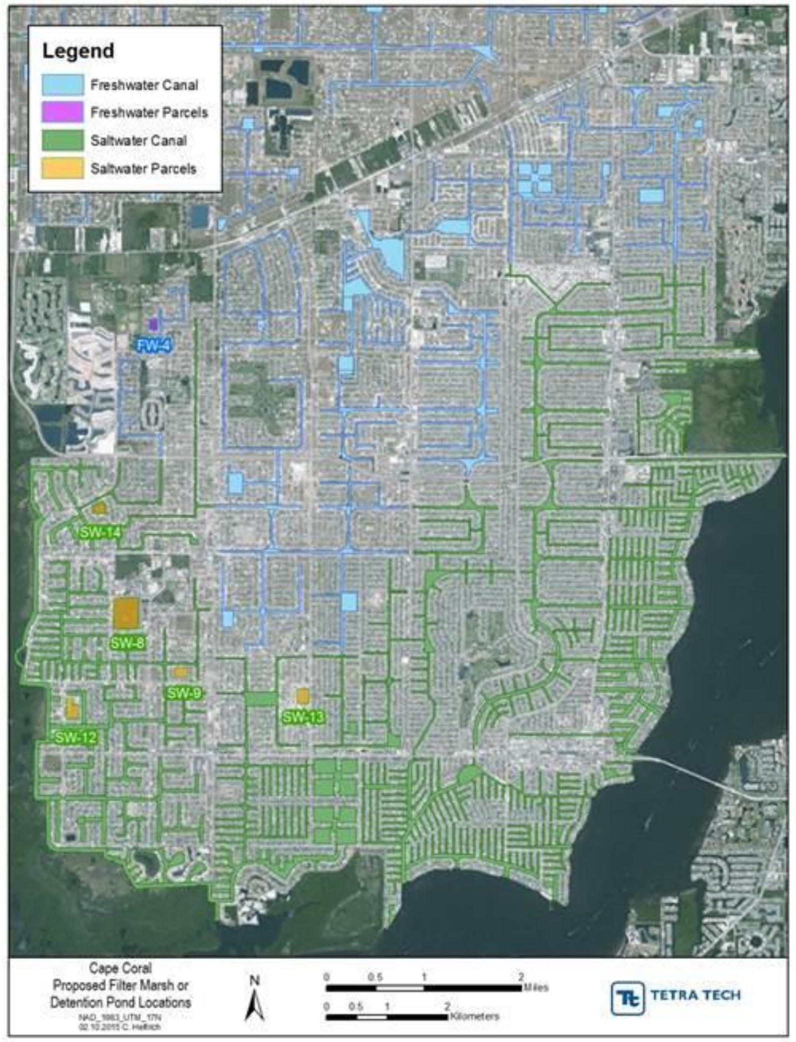


Pollutant Removal Process in a Wetland

TETRA TECH

EXHIBIT A.10

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: CITY-WIDE FILTER MARSH/DETENTION POND TREATMENT



City of Cape Coral City Owned Vacant Parcels

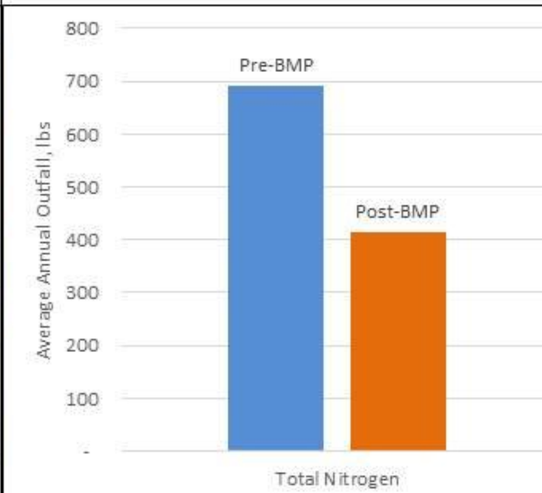
Project site, on 42nd Street SW facing ENE

Project site, on 42nd Street SW facing ENE

Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

Planning	$14,325
Design	$143,247
Contingency	$107,435
Mobilization	$14,325
Construction	$716,235
20-year O&M	$25,734
Total Cost	**$1,021,300**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Total Nitrogen, (lbs)	692	415	277	40%



TETRA TECH

EXHIBIT A.10

11. P1-1016: Cape Coral Yacht & Racquet - Parking Lot Retrofit

Project Location and Description

The project is located within the Cape Coral Yacht & Racquet parking lot. A portion of the contributing drainage area is a parking lot used for boat trailer parking. Residential housing and parking for the Yacht & Racquet also contribute to this project area. Figure A.11-1 shows the project location and contributing drainage area.

Figure A.11-1. Project Location for Site P1-1016

This project proposes replacing a portion of the auxiliary parking area with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for the City, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here. Boating activities often produce contaminates which makes treating boat trailer parking lots an effective project.

The total contributing drainage area is approximately 4.1 acres and includes the boat trailer parking, half of the tennis court parking and residential areas as shown in Figure A.11-2.

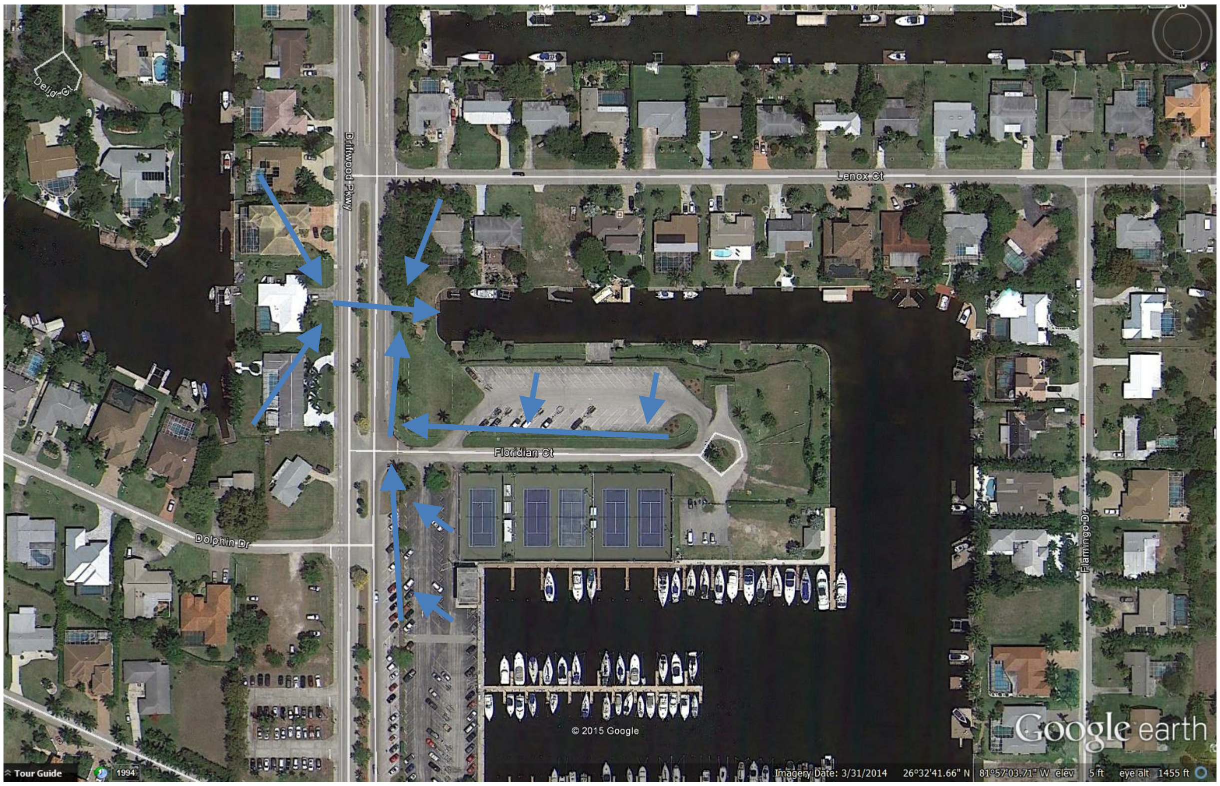


Figure A.11-2. Existing Drainage Patterns for Site P1-1016

BMP Sizing

As a general guideline, bioretention should occupy at least 5 to 7 percent of the drainage area to treat the first inch of runoff (first flush). Other guidance, such as that provided by EPA, recommends that bioretention treat the 85th to 95th percentile storm event which for the City was calculated to be about 1.27 to 2.19 inches respectively. Because this BMP is being implemented as a retrofit to improve the overall water quality of the City and to work towards meeting the requirements of the Caloosahatchee BMAP, site constraints, existing dimensions, and cost are the main considerations regarding size. However, the guidelines mentioned above are important factors in determining whether a site has adequate area for effective treatment. For this project, the initial conceptual configuration for bioretention treated the entire drainage area in Figure A.11-2. The initial configuration represented about 2.79 percent of the drainage area. Therefore, the conceptual configuration was modified to only treat stormwater from the boat parking lot and bypass the existing storm drain volume. This design will likely result in a more efficient BMP.

BMP Conceptual Layout

The suggested BMP configuration is intended to convert the existing grass parking area into bioretention in order to capture concentrated sheet flow from the boat trailer parking lot for treatment. The location utilizes the existing drainage patterns and is configured "on-line" to minimize excavation, grading, demolition, and piping. The BMP configuration and typical cross-section details are provided in Exhibit A.7.

Overflow Structure

During on-line flow all runoff from the drainage area flows into the bioretention system. Flows that exceed the design capacity exit the bioretention area via an overflow structure or weir. The following considerations should be included in the final overflow design:

- The overflow device must convey runoff to the storm sewer.
- Common overflow systems within bioretention consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically between 6 to 12 inches above the surface of the filter bed.
- The overflow device should be scaled to the application.
- At least 3 to 6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.

Soil Media

The bioretention cells should be designed to have soil media that meets the following specifications:

- For safety and ease of maintenance, side slopes should be no steeper than 3h:1v.
- At least 18 inches of soil media should be added above the underdrain layer to create an acceptable filter.
- The soil media should be obtained from an approved vendor (or manufactured onsite to acceptable specifications) to create a consistent, homogeneous fill media.
- The soil media should have a porosity of 30 percent and be capable of infiltration rates of 0.5 in/hr or greater under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/acts), and should not be hydrophobic.
- The soil media should contain some organic matter for increased water holding capacity but be low in nutrient content.

The recommended soil mixture and recommended media testing and specified ranges is shown in Table A.11-1.

Table A.11-1. Soil Media Specifications

Material	Specification	Notes
Filter Media Composition	• 85-88% sand • 8-12% soil fines • 3-5% organic matter in form of leaf compost	The volume of filter media should be based on 110% of the product of the surface area and the media depth, to account for settling.
Filter Media Testing	• Mehlich-I Extractable mg/kg = 10-25 (This is enough phosphorus to support plant growth without exporting phosphorus from the cell.) • Cation Exchange Capacity (CEC) greater than 10 • Soil pH between 5.5 and 7.0 • Mix on-site or procure from an approved media vendor	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter	
Permeability	Infiltration should be 0.5 in/hr or greater	

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will contain anywhere from 30 to 50 percent soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. An additional 3 to 5 percent organic matter can then be added. (The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material.)

Choking Layer

A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Underdrains

The underdrain should be 4 or 6 inch perforated schedule 40 PVC pipe with 3/8 inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The number and diameter of the underdrains used must be sized so that the bioretention system fully drains within 72 hours or less.

Plant Selection

For the bioretention cells to function properly as stormwater treatment and enhance the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
- It is recommended that a minimum of three tree, three shrub, and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions. However, a selection of plant species, along with additional details including the recommended spacing, container size, and light requirements, is provided in Table A.11-2.

Table A.11-2. Plant Species for Bioretention

Common name	Scientific Name	Spacing	Container Size	Light
Dahoon holly	Ilex cassine	10' O.C.	3 gal	full sun to partial shade
Cabbage palm	Sabal palmetto	10' O.C.	3 gal	full sun to partial shade
Wax myrtle	Myrica cerifera	5' O.C.	1 gal	full sun to partial shade
Shyny lyonia	lyonia lucida	5' O.C.	1 gal	full sun to partial shade
Dwarf yaupon holly	Ilex vomitoria cv.Schellings	5' O.C.	1 gal	part shade/part sun
Saw palmetto	Serenoa repens	5' O.C.	3 gal	full sun to full shade
American beautyberry	Callicarpa americana	5' O.C.	1 gal	part shade/part sun
Sand cord grass	Spartina bakeri	5' O.C.	1 gal	full sun
Blue maidencane	Amphicarpum muhlenbergianum	3' O.C.	4" pot	partial shade
Muhly grass	Muhlenbergia capillaris	3' O.C.	1 gal	full sun

Notes: Planting elevations relative to established water surface elevations. O.C. = on center

Operations and Maintenance

Maintenance activities should be focused on the major system components, especially landscaping and the overflow structures. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance. The primary maintenance requirement for the overflow structures consists of regular inspection for clogging.

Irrigation for the bioretention cells might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than non-native plants.

Table A.11-3 outlines the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task.

Table A.11-3. Maintenance Tasks for Bioretention

Task	Frequency	Maintenance Notes
Monitoring infiltration and drainage	1 time/year	Inspect drainage time (12-24 hours). Might have to determine infiltration rate (every 2-3 years). Turning over or replacing the media (top 2-3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on the location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining 1"-3" uniform mulch layer.
Mulch removal	1 time/2-3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Total Nitrogen Load Impacts

SUSTAIN was used to quantify potential water quality benefits achieved by implementing the bioretention BMP. The simulations were run for a 17 year period from January 1, 1996 through December 31, 2013. Table A.11-4 and Figure A.11-3 highlight the total annual load reduction for total nitrogen (TN). Time series data were available from the model. Water quality benefits are realized through loss of pollutant mass via infiltration by increasing the residence time and through pollutant uptake from the vegetation within the BMP.

Table A.11-4. SUSTAIN Model Load Reductions for Site P1-1016

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume (ft^3)	131,938	43,598	88,340	67%
Total Nitrogen (lbs)	19	2	17	88%

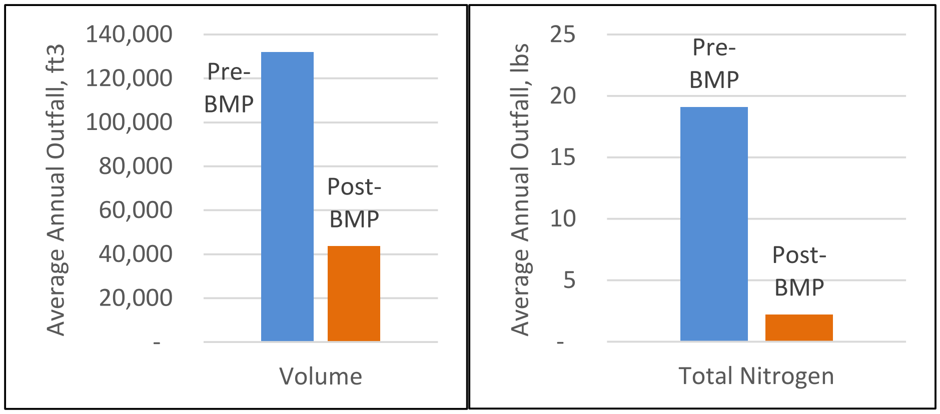


Figure A.11-3. SUSTAIN Model Load Reductions for Site P1-1016

Cost Opinion

The estimated costs of implementing bioretention at Cape Coral Yacht & Racquet parking lot are presented in Table A.11-5. These costs are presented for planning purposes only. Actual costs will likely vary from those presented here. The cost per pound removed of TN for this BMP is estimated to be about $5,083.53.

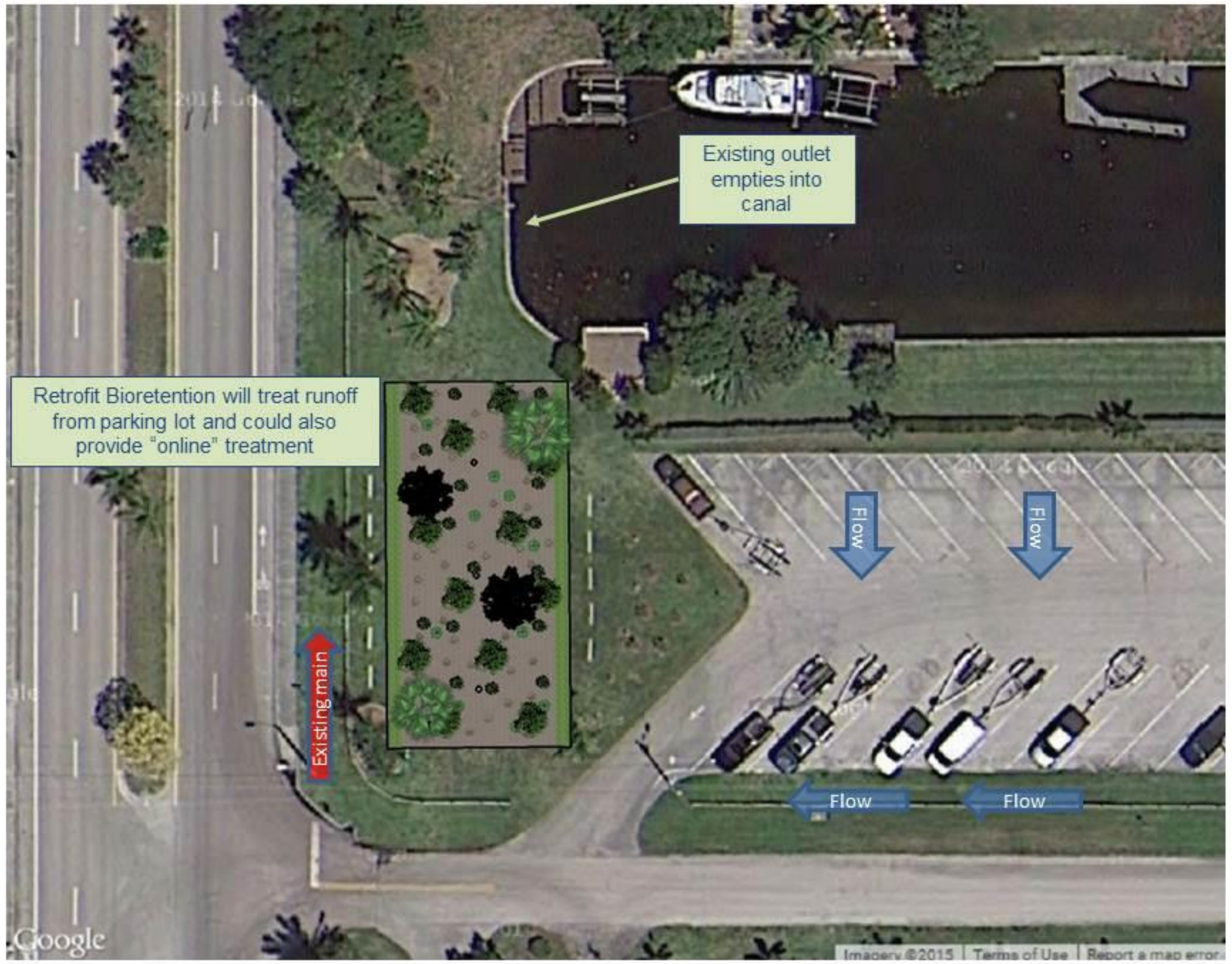
Table A.11-5. Cost Opinion

Item No	Description	Quant.	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	340	LF	$2.50	$850.00
2	Silt Fence	340	LF	$3.00	$1,020.00
	Site Preparation				
3	Excavation and Removal	750	CY	$8.52	$6,390.00
	Bioretention				
4	4 inch Perforated Pipe	800	LF	$2.00	$1,600.00
5	Gravel Subbase - 6 inches	5,000	SF	$0.55	$2,750.00
6	Fine Grading	5,000	SF	$0.72	$3,600.00
7	Soil Amendments	100	CY	$13.00	$1,300.00
	Landscaping				
8	Vegetation	5,000	SF	$4.00	$20,000.00
Construction Subtotal					**$37,510.00**
9	Utility Adj (5% of subtotal)				$1,875.50
10	Planning (10% of subtotal)				$3,751.00
11	Design (40% of subtotal)				$15,004.00
12	Mobilization (15% of subtotal)				$5,626.50
13	Contingency (30% of subtotal)				$11,253.00
Construction Total					**$75,020.00**
14	20-Year O&M	5,000	SF	$2.28	$11,400.00
Total Cost					**$86,420.00**

Design Details and Drawings

The conceptual plan and cross-section details are provided in Exhibit A.11.

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1016



Project Narrative

This project proposes replacing a portion of the auxiliary parking area with bioretention. Bioretention cells are depressions filled with 1.5 to 3 feet of engineered soil media and planted with drought and flood tolerant plants. The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet. Stormwater drains into the surface of the bioretention cell and, as the water infiltrates through the soil media, the soil and plants remove a portion of pollutants. Once the stormwater infiltrates through the treatment cell's soil media, it is drained into the native soil or out of the device through an underdrain pipe. Most bioretention cells are designed so that between a half foot and one foot of water can pond in the cell during a rain event. A weir is included in the bioretention cell to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping. These types of devices are a good option for Cape Coral, particularly for new parking lots and as a retrofit for existing parking lots as is being proposed here. Boating activities often produce contaminates which makes treating boat trailer parking lots an effective project.

Site ID	P1-1016	Latitude	26° 32' 40.91" N
Project Name	TBD	Longitude	81° 57' 04.95" W
Date of Field Visit	12/08/2014	Street Address	Driftwood Parkway
Field Visit Personnel	EB, DS	Landowner	City of Cape Coral

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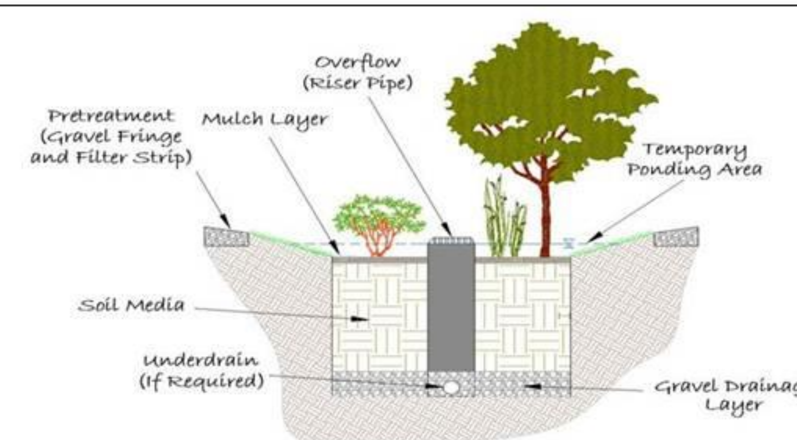
Project site, parking lot entrance/exit facing north

Project site, parking lot entrance/exit facing north with proposed Bioretention



Example Bioretention Retrofit Cross Section

EXHIBIT A.11

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: P1-1016

Project site, view from Driftwood Parkway facing southeast

Project site, view from Driftwood parkway facing southeast with proposed Bioretention

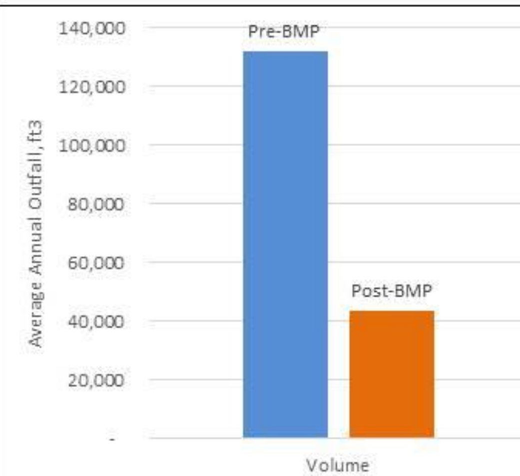
Benefits	
Peak Flow Attenuation	✓
Nutrient Uptake	✓
Sediment Removal	✓
Beautification	✓
Improved Stream Function	

Aerial view of the proposed project site

Aerial view of the proposed project site with Bioretention

Planning	$3,751
Design	$15,004
Contingency	$11,253
Mobilization	$5,627
Construction	$37,510
20-year O&M	$11,400
Total Cost	**$86,420**

Constituent	Average Annual Loads		Average Annual Reduction	
	Pre-BMP	Post-BMP	Reduction	Percent
Volume, (ft3)	131,938	43,598	88,340	67%
Total Nitrogen, (lbs)	19	2	17	88%



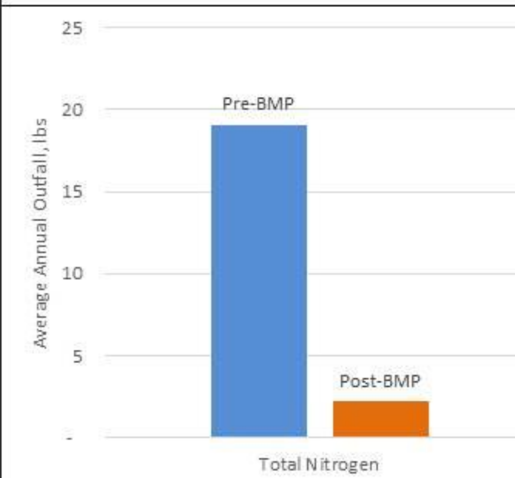


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EXHIBIT A.11

12. Street Sweeping

Project Location and Description

The Street Sweeping program is the City's first line of defense against waterway pollution. It has been implemented to pick up debris on curbed and guttered streets, bike lanes, parking lots, and alleys within the City. Street sweeping helps prevent silt from entering the canal system, and beautifies roadside areas in the sweeping program. Since April 2011, this program has been performed by outside contractors, on the City's behalf, primarily south of Pine Island Road (State Road 78). Street sweeping is required per the MS4 NPDES permit, and by monitoring the totals of the swept material, the city receives BMAP credits. This concept is for expanding the areas currently being swept to other parts of the City, mainly residential areas below Pine Island Road. The roadways that were identified as candidates for expanded street sweeping in the City can be seen in Figure A.12-1.

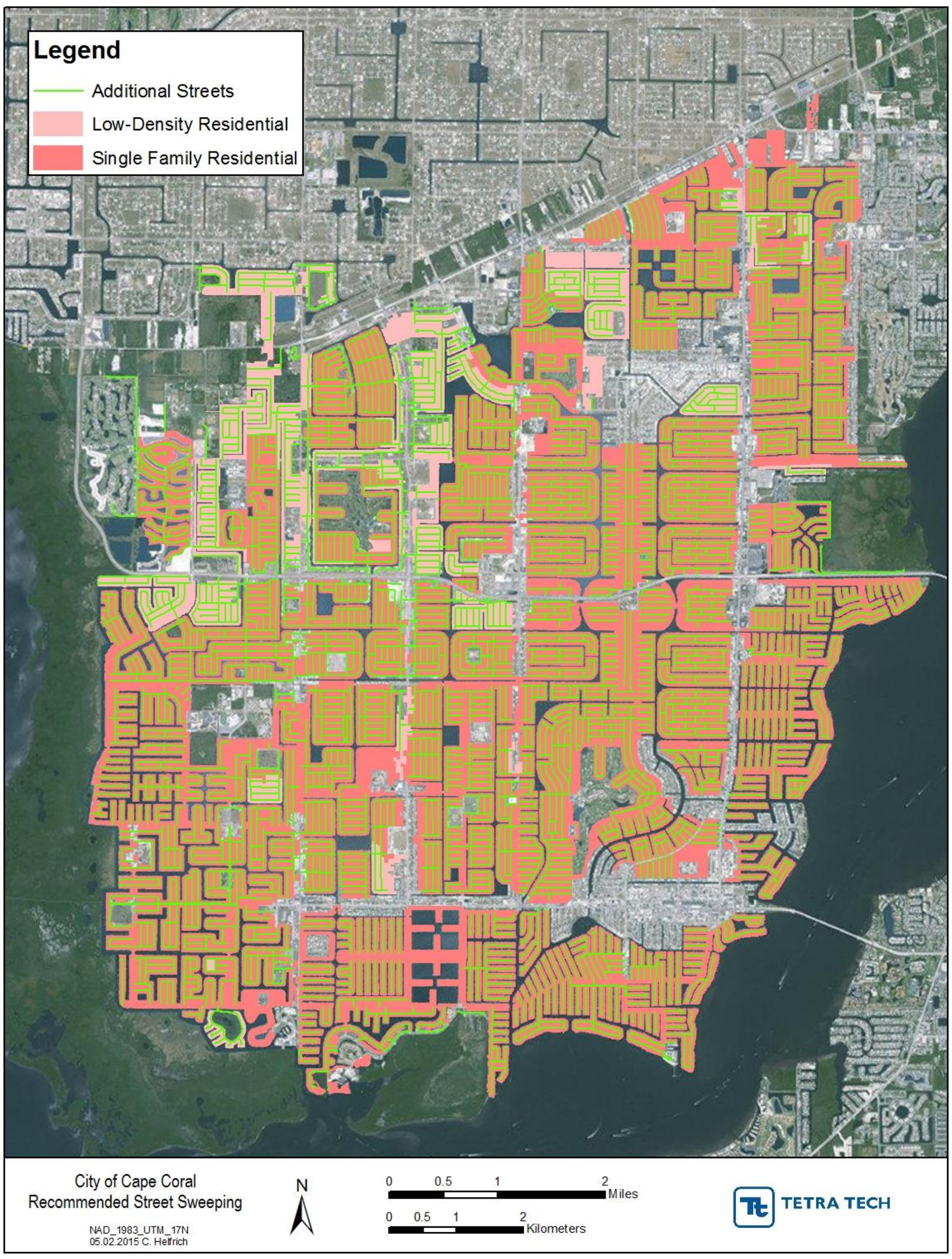


Figure A.12-1. Proposed Expanded Street Sweeping Routes

The amount of TN credit for the expanded street sweeping program can be estimated by using data from the current program and the FSA Load Reduction Assessment Tool (Assessment Tool). The Assessment Tool is based on the 2011 Final Report (Sansalone et. al. 2011), and provides quantified values of the mass fraction of TN and TP associated with solids typically accumulated in BMPs, catch basins, and those solids collected by street sweepers. The use of this tool allows municipalities to provide fairly rudimentary measurements of weight or volume of material removed, while generating scientifically defensible values for the associated TN and TP.

All nutrient calculations resulting from use of the Assessment Tool are related to the weight or volume of solids removed. Accordingly, operation and maintenance staff must measure either the volume or weight of material removed. At least initially, there is no substitute for actual measurements. Note that
it is anticipated that after some period of data collection and/or calibration of frequently used equipment, that certain "rules-of-thumb" may be used to estimate the weight or volume of solids with a high degree of confidence. For example, after numerous measurements related to the volume of a "full truck," it should be possible to estimate the field weight of the solids, when the truck is full. Over time, perhaps one year, municipalities may have enough data collected to "calibrate" their various equipment types and transport vehicles in order to simply "count trucks" (as a simplified example). In every case, maintenance activities and associated weights or volumes of solids must be measured or accurately estimated, and then recorded. These data should be summarized and tracked (for example, in an Excel spread sheet) by the maintenance supervisor or director's office on a routine, regular basis. The following reference provides additional details about the assessment tool and how it can be used to gain BMAP credit.

METHODOLOGY FOR CALCULATING NUTRIENT LOAD REDUCTIONS USING THE FSA ASSESSMENT TOOL

By Michael Bateman, P.E., NWFWMD, for:
Florida Stormwater Association and Florida Department of Environmental Protection
January 2012

Tetra Tech estimated that in 2014, the City performed street sweeping on about 8,560 miles based on the actual street sweeping budget of $299,632.20 and per mile cost of $35.00. Using the assessment tool, Tetra Tech back calculated the total amount of particulate matter collected to be 811,715 pounds or about 43 kg per mile swept. Therefore, the City's annual TN reduction credits from street sweeping suggest that the particulate matter removed annually under the current street sweeping program is very close to the lowest value of the range reported in *Quantifying Nutrient Loads Associated with Urban Particulate Matter (PM), And Biogenic/Litter Recovery Through Current Ms4 Source Control And Maintenance Practices,* which is a report accepted by the Florida Stormwater Association. The report identified a range of 40.8 kg to 1130 kg of particulate matter per mile swept.

Table A.12-1. Current Street Sweeping Program Removal Efficiency

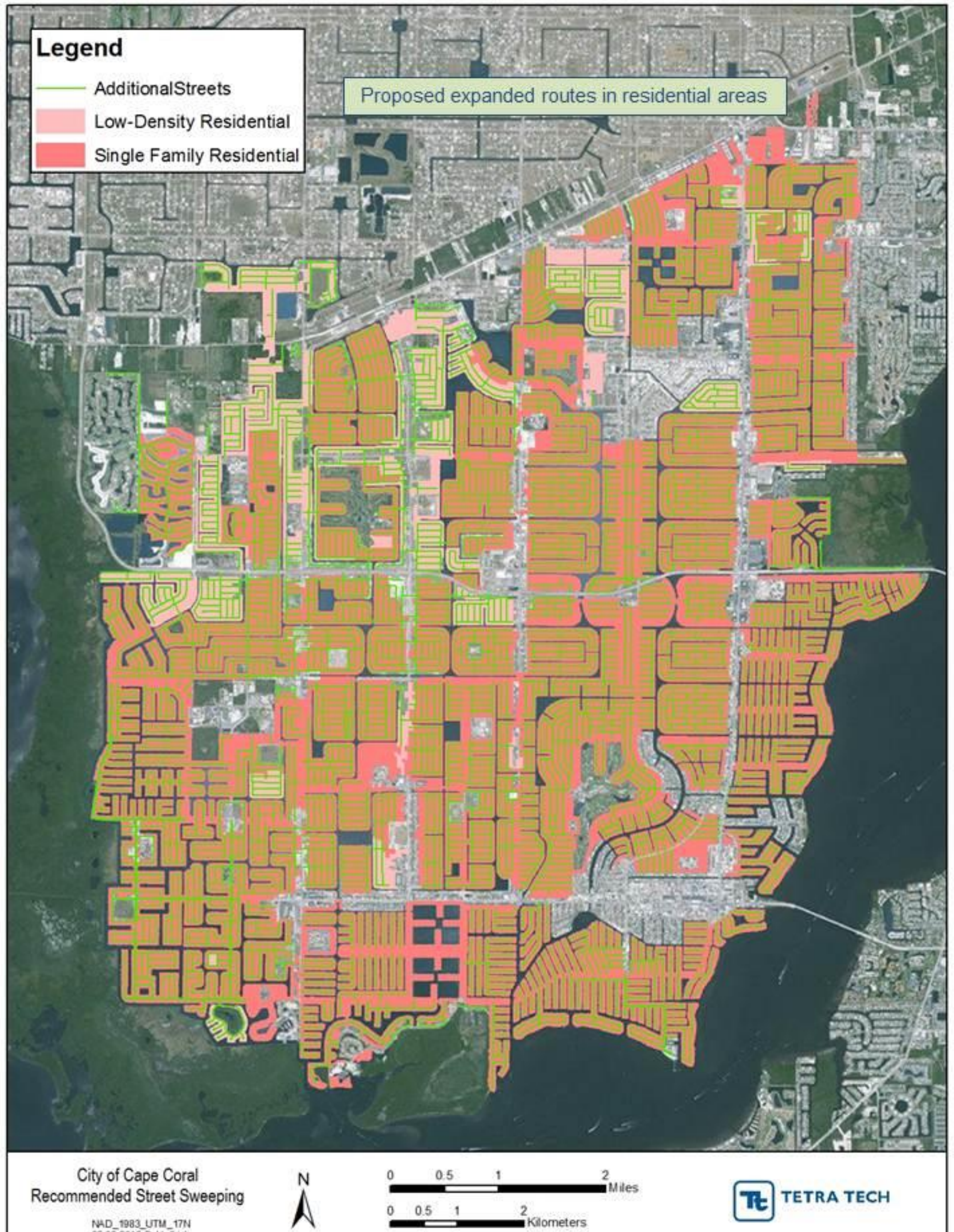
Miles Swept/yr	TN Removed (lb)	Annual Cost	Annual Cost/lb Removed
8,560	457	$ 299,632.20	$ 655.65

Tetra Tech conducted a hypothetical preliminary street sweeping analysis for the expanded area. Potential TN load reductions and costs were calculated using the same rates determined for the current street sweeping program. Therefore, the current particulate matter load recovery of 43 kg/mile at a cost of $35.00 per mile was used. Results of the hypothetical analysis are shown in **Error! Reference source not found.**.

Table A.12-2. Hypothetical Street Sweeping Program Expansion Removal Efficiency

Land Use	Curb Miles Swept/yr	PM/mile (kg)	TN lb removed	Cost	Cost/lb removed
Residential	13,294	43	710	$465,290	$ 655.34

The hypothetical results show that about 710 pounds of TN can be removed for about $465,290, resulting in a rate of $655.34 per pound. However, these values are based on the assumption that the expanded area will deliver the same 43kg per mile of particulate matter as the current routes. The aforementioned report identified a range of 40.8 kg to 1130 kg of particulate matter per mile swept. The low end of the range results in the removal of approximately 660 pounds of total nitrogen at a cost of approximately $704.98 per pound while the high end of the range results in the removal of approximately 18,649 pounds of total nitrogen at a cost of approximately $24.95 per pound. While we don't believe that the expanded route will hit the high end, it would be worthwhile to "test" some of the expanded area streets and extrapolate those results to estimate how much particulate matter could be expected.



Project Narrative

Street sweeping has proven to be an effective means of removing metals, nutrients, and hydrocarbon constituents that are found in streets and are characteristic products of vehicular traffic. Reducing the amount of harmful street debris and other pollutants that would usually be carried by stormwater runoff has major implications on downstream water quality. A typical street sweeping program involves the deployment of street sweeper fleets on targeted routes based on schedules defined by desired load reduction goals. Other logistical considerations include a public awareness campaign, namely signage, to ensure that parking along routes is discouraged.

Typical scene on Cape Coral Parkway

Typical scene on Cape Coral Parkway with proposed street sweeper

CITY OF CAPE CORAL WATER QUALITY MANAGEMENT PLAN
LOCATION: CITY-WIDE STREET SWEEPING

TETRA TECH

EXHIBIT
A.12

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Appendix B: Compendium of Indicators for Prioritizing BMP Opportunities

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The following indicators were considered in various ranking configurations during early iterations of the prioritization screening but failed to adequately highlight priority parcels:

- Proximity to WQ Stations
- Proximity to Stormwater System
- Public/Private – Improved/Unimproved
- Parcel Imperviousness

The following indicators may be considered in future iterations:

- Development Density (Bioswale Retrofits)
- Private Commercial/Industrial Facilities without Existing BMP Treatment
- Located in a Priority Characterization Area
- Proximity to Existing BMP
- Proximity to Maintenance Need
- Proximity to Stormwater Structural Damage
- Land Use
- Canopy Cover
- Contaminated Sites
- Space Requirements